Compressed Air

DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

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Compressed Air.

A MONTHLY PUBLICATION DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

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The widening use of compressed air in the arts has developed a great many types of Air Compressors and has distinctly improved the efficiency of the machine. A few years ago it was an uncommon thing for an Air Compressor builder to supply a machine with compound air cylinders; to-day the best Compressors are of the compound type and an engineer who specifies an Air Compressor for his plant, is wise if he looks carefully into the tender submitted, especially with reference to compounding and intercooling. It is quite as important in large plants that the air cylinders be compounded, as that compound steam cylinders are used, and it is equally as important to supply efficient intercoolers as to use a condenser on the steam end.

There is, naturally, at the present time, but little general familiarity with Air Compressors and compressed air machinery; hence, when those in charge of works decide to install a Compressor, they are at a loss to know how to draw up the specifications or to decide which of the numerous types is preferable. The plan which might be called European, and which applies to machinery and constructive work generally, is to send out specifications and ask for bids. This is a dangerous thing to do unless the person who draws the specifications is thoroughly familiar with the subject. Such familiarity is not likely to exist in places where Air Compressors are required; hence, it is of greater importance to investigate the question as to the experience and standing of the bidder.—How long has a certain concern been building Air Compressors? What shop facilities they have for turning out the work, and what is the general design of their machine. A first-class builder of large experience and a growing business might naturally be expected to supply something of a high class in this line, and yet it may be found, on investigation, that this builder has a specialty that his machines are mainly used for light duty or low pressures, or vice-versa. References and testimonials are easily given and are only of value in connection with a case of this kind in so far as they point to the class of trade which the manufacturer has been supplying, and if the buyer is not in too much of a hurry, he will do well to investigate the references. In connection with this subject, the following specifications have been brought to our notice as having been submitted to builders of Air Compressors, by two of the largest concerns in the country. They may be of interest to our readers as indicating types of specifications which are sent out when calling for bids:

"Dimensions of steam and air cylinders to be determined by maker; to be of sufficient size for compressing 650 cubic feet of free air per minute, to 750 pounds per square inch in three stages, at a maximum piston speed of 400 feet per minute. Initial pressure of steam 80 pounds, taken from a steam line 175 feet in length, from boiler to compressors. The whole machine to be designed to withstand 1250 lbs. pressure in third compressing cylinder.

"Builder to furnish complete plans and detail specifications, templates, foundation bolts, oil cups, sight feed lubricator, exhaust pipe, wrenches, and all fittings to make compressor complete for making trial test; also to furnish, at builder's expense, a competent machinist to superintend the erection of compressor, the buyer to furnish all unskilled labor and prepare the foundations for receiving compressor."

"CAPACITY.—Capacity of compressor 600 to 650 cubic feet of free air per minute, compressed to 100 pounds per square inch, with 100 pounds per square inch steam pressure.

"SPECIFICATIONS. — Signed specifications to be furnished covering workmanship, guarantee in regard to same, details of various parts, tools with compressor, time of delivery after ordered, etc.

"PLANS.—Foundation plans and print showing plan of compressor giving general dimensions, location of pipes, etc. Also photograph or catalogues and page number where compressor is shown to be furnished.

GENERAL INFORMATION TO BE GIVEN.

"Type of compressor.

"Diameter of steam and air cylinders with stroke.

"Free air capacity per minute.

"Piston speed.

"Revolutions.

"Sizes of pipes.

"Floor space.

"Price.

"Point of delivery."

These specifications are conspicuous for their simplicity in that they throw the entire responsibility upon the maker. It is evident that if a maker is called upon to build something not strictly in line with his practice, or which is based upon the design of some other maker, he is not likely to do the subject justice and the buyer will run some risk in placing the order with him, because it will be more or less experimental. Air Compressors can only be built well when based on experience. The best design made by the best men will fail unless tested and developed on lines of practice.

For a few years past chimes in church towers have been coming into favor. A number of cities in European countries have orchestras of this kind, that date back to the 17th or 18th centuries. There are several in this country and every one of them have had the problem of how to ring them to contend with. This question has been so filled with obstacles, that even after the bells were bought and hung in place they have remained silent.

Pious persons of wealth knowing of no other lasting gift to make their favorite church, have bequeathed or presented chimes, leaving the ringing of them to the church itself. We know of one case where there are 44 bells and no music has been obtained from them, although they have been in place for many years. The ringing of chimes is a work, however, that is never wholly abandoned by church trustees, consequently, some of these churches have erected crude appliances, that ring the bells in a more or less satisfactory manner. Electricity has been the hope of many, and there are places where bells are rung by electric appliances, but they have never proved satisfactory. The chime bells of St. Germain-L'Auxerrois, in the city of Paris, were finished in 1878. Their construction extended over a period of 15 years, and yet they never rang successfully until last year. To show the system employed in that instance, we present a picture of the key-board, cylinder and mechanism of these chimes. The system as a whole occupies a space of no less than 60 ft. in height, and an octagonal surface of 108 square ft. The weight room is 19 ft. in height by 11½

in width. The cylinders of the bell weights have diameters varying from 10 to 52 inches; each cylinder with its wheel work, accessories, and striking train constitutes a true clock.

It is said that these bells will welcome visitors to the Paris Exposition next year.

One of the finest set of chimes in the United States is that of St. Patrick's Cathedral, 5th Avenue, New York City. Nineteen bells constitute the set, and they were donated by Cathedral Parishioners and others.

THE FOLLOWING LIST GIVES THE WEIGHT AND TONE OF EACH OF THE BELLS, AND THE NAME OF THE DONOR.

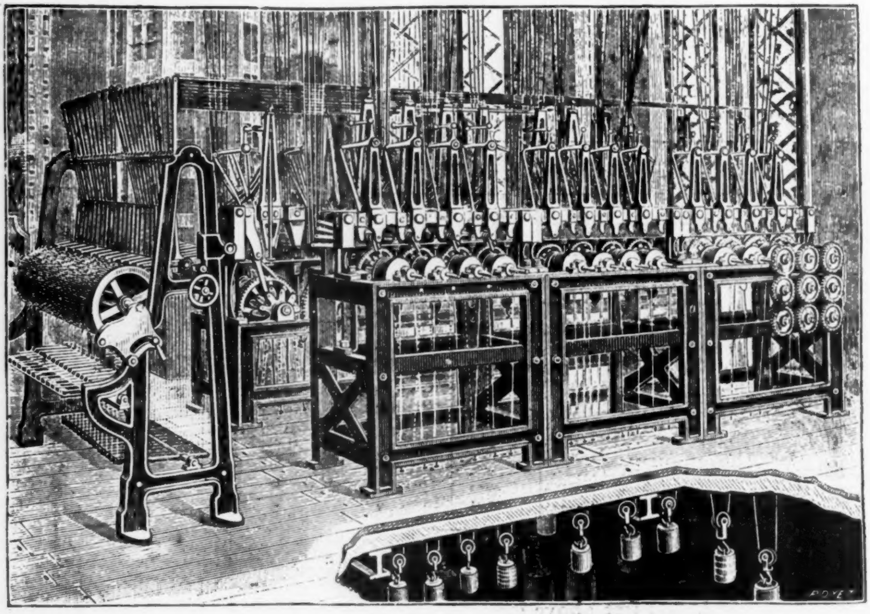
	NAME OF BELL.	TONE.	WEIGHT IN POUNDS.	DONOR.
1	St. Patrick	B flat	6,300	Cathedral Parishioners.
2	Our Lady's	C	4,400	John B. Manning.
3	St. Joseph	D	3,300	Joseph J. O'Donohue.
4	Holy Name	E flat	2,600	The Sodalities of the Holy Name throughout the city.
5	St. Michael	E	2,200	Michael S. Coleman.
6	St. Ann	F	1,850	Henry McAleenan.
7	St Elizabeth	G	1,300	The Marquise San Marzano.
8	St. Augustine of Hippo	A flat	1,100	Augustine Daly.
9	St Anthony of Padua	A	965	In memory of Edward Fox
10	St. Agnes	B flat	770	In memory of James Edward Fox.
11	St John Evangelist	B	650	John D Crimmins.
12	St. Bridget	C	550	In memory of Aloysia Miniter.
13	St. Francis Xavier	C sharp.	460	The Catholic Club.
14	St. Peter	D	385	George B Coleman.
15	St Cecilia	E flat	330	Mrs Thomas F. Ryan.
16	St. Helena	E	275	Eleonora Keyes.
17	St Alphonsus Liguori	F	220	Maria A Mills.
18	St Thomas Aquinas	F sharp.	200	Thomas Kelly.
19	St Godfrey	G	163	In memory of John and Mary Koop.

These bells hang in the northern spire of the Cathedral, 180 feet above ground. The following ritual of the bells will be observed. The Angelus will ring at 8 a.m. 12 m. and 6 p. m. daily, and the De Profundis bell will ring daily at 7 p. m. The chimes will play on Sundays and greater festivals or national holidays, and pious occasions. The bells will be tolled at funerals.

The same perplexing question arose when these bells arrived from France, where they were made. A committee was appointed by His Grace, Archbishop Corrigan, with Mr. Cornelius O'Rielly as Chairman, and Fathers Connolly and Lavelle, and Mr. John A. Sullivan as members. The subject was gone into thoroughly and all of the various systems examined exhaustively. Every one of the systems then in vogue seemed by this committee inadequate and lacking the modern facilities that marked almost every other method of doing things. The crudeness of methods, expense of installation and the necessity of having expert attendants caused all systems known to be rejected. Many propositions were submitted. The bells were installed in the Cathedral spire in the autumn of 1897. In December, 1897, this magazine printed the following: "An inquiry comes to us asking for the services of some compressed air genius who can devise a practical compressed air apparatus for ringing chime bells. A short time ago 19 stationary chime bells, the heaviest of which is about 6,000 pounds, and the lightest about 300 pounds, were placed in St. Patrick's Cathedral, New York. It was intended to ring them by electricity, but thus far no device has been acceptable. It has been suggested that by

a suitable installation compressed air would do the work satisfactorily. The church authorities will lend any assistance to enable experiments to be carried on, providing the plan submitted appears feasible."

This was the signal for work in this direction. Several compressed air experts came forward with sketches and designs to cover the requirements of these bells. The committee secured expert advice and finally accepted the system submitted by Mr. Hertford C. Champ, of New York, who had been a reader of "Compressed Air," and who had made this subject his study. His plan was so simple and embodied the essential features to such extent that this system was finally adopted and the work begun. The plan as installed consists of compressed air and electricity, the one being the motive power causing the bells to ring, and the other being employed as the means of operating the mechanism which strikes the bells. Chime bell ringing by compressed air had never been tried before, and Mr. Champ's genius has been severely taxed to complete a system that will in all probability be the most complete one ever used for this purpose. Following the proposition from the beginning we find a complete air-power plant consisting of an Ingersoll-Sergeant, Class "E" compressor, with air cylinder 8 in. diameter by 8 in. length of stroke, driven by a 15 H. P. 240 volt direct current six pole type Lundell motor, made by the Sprague Electric Co. These machines are rigidly mounted upon a heavy cast iron base plate designed and finished in Mr. Champ's shop, and set on a rock



KEYBOARD, CYLINDER AND MECHANISM OF THE CHIMES OF SAINT-GERMAIN-L'AUXERROIS.

foundation in the sub-basement of the Cathedral Rectory. The armature of motor is fitted with a pinion meshing into a cut spur wheel fitted on one end of the compressor crank shaft. This power unit is considered extremely compact in its dimensions, runs remarkably well, and is capable of supplying the equivalent of 69 cubic feet free air per minute, which air is taken from a deep and decidedly cool area-way alongside the power room, and is delivered into a receiver 6 feet high by 24 in. diameter, from which latter the air power is conducted through a 2 in. pipe a distance of 600 feet to another receiver in the belfry. The two receivers have sufficient storage to at all times cause the bells to ring when they are wanted. Air is compressed to 80 pounds, so that there is always surplus for any emergency that may arise. A 2 inch pipe is carried as a main line, passing under each bell. From this main supply pipe, which is of itself a reservoir of air, ¾ in. connections are made with the striking mechanism. After we have compressed the air we find it within 2 inches of the piston that moves the clapper to strike the bell. The key-board is located in the sacristy of the church. A cable is led to the church spire, and wires are connected to the magnet of the striking mechanism. Both the powers are here controlled from a distance. The operator at the key-board presses a key corresponding to the bell that he wishes to have struck. This makes an electric connection which serves to open a valve admitting compressed air to a piston connected with a clapper which strikes the bell. Electricity is the trigger and compressed air the power in this work. There can be no measurable delay in the stroke. A duplication of this operation brings the nineteen bells under the control of the operator in the sacristy, where by means of the key-board showing the notes of the bells he rings the chimes to any air desired. The details as described show the practicability of this system.

CHIMES OF ST. PATRICK'S CATHEDRAL.

Traction and Auto-Mobile

Air Plant of the Metropolitan Street R'y Co. in New York.

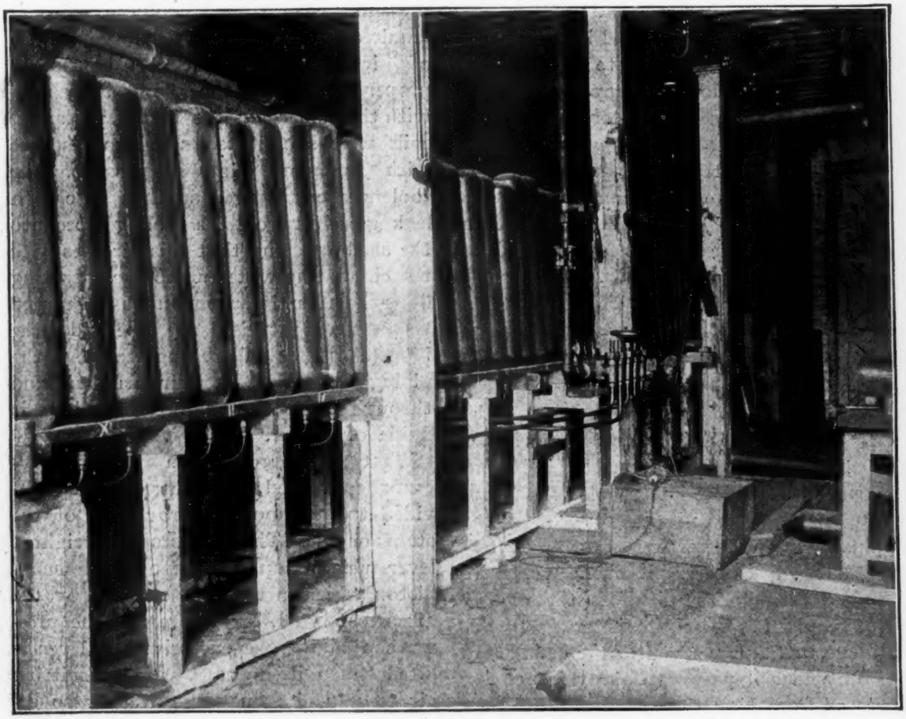
A compressed air plant, unusual in almost all of its features, and embodying characteristics in design and construction far in advance of ordinary practice, has just been completed by the Ingersoll-Sergeant Drill Co. of 26 Cortlandt Street, New York. The installation was made for supplying the air motors on the cars of the Metropolitan Street Railway Company of New York. The station is located at 23d Street and North River.

The Vertical Four Stage High Pressure Air Compressor used for supplying Power for Street Car Service on the 28th and 29th Street Lines, New York

The plant is uncommon mainly for two reasons, its great efficiency in producing compressed air and the high pressure obtained. High pressures with small machines are common, but pressures of 2,500 pounds to the square inch in 1000 horse power machines are new. In general the machine consists of a duplex vertical cross compound engine built by the E. P. Allis Company of Milwaukee, which has cylinders 32 inches by 68 inches and 60 inches stroke, provided with Reynolds Corliss valve gear. With steam pressure of 150 pounds, furnished by Babcock & Wilcox boilers and 40 revolutions per minute the horse power is 1,000. The shaft is of hammered iron 22 inches in diameter outside of the journals, 20 inches diameter in the bearings, which are 36 inches long. The fly wheel placed between the cylinders, as shown, is 22 feet in diameter and weighs 60 tons. The engine is mounted upon brick piers, and directly underneath it is placed

The Air Compressor.

This machine is of the 4 cylinder type, the low pressure cylinder being 46 inches, the first intermediate 24 inches, the second intermediate 14 inches, and the high pressure cylinder 6 inches in diameter, the stroke being common with the engine, 60 inches. All of these are single acting.



BATTERY OF STORAGE TUBES, IN WHICH AIR IS KEPT AT 2,500 POUNDS PRESSURE, AND FROM WHICH THE CARS ARE CHARGED.

The free air capacity per revolution is 56.735 cubic feet; capacity at 40 revolutions 2269.4 cubic feet, and the free air capacity at 60 revolutions is 3404.1 cubic feet. The approximate pressure in the first cooler is 40 pounds, in the second 180 pounds, and in the third 850 pounds, the final approximate pressure in the after cooler being 2,300 pounds.

The compressor pistons are arranged in pairs vertically in line beneath the steam cylinders, as is shown in Fig. 1, the initial and first intermediate air cylinder being below the low pressure steam cylinder, while the second intermediate and high pressure air cylinders are below the high pressure steam cylinder. Motion is transmitted from the steam engine cross heads through distance rods for each cross head to a cross head attached to the air cylinder piston rods.

The inlet and discharge valves of the initial air cylinder are of the "Mechanical" type and of a special design. These valves are shown at K Fig. 1. Air is admitted to the top of this cylinder through the supply pipe *a*, and leaves the cylinder through the pipe *a'*, by which it is conducted to the first inter cooler E. From the cooler E the air flows through the pipe *b'* to the lower end of the first intermediate air cylinder B from which it passes through the pipe *b* to the second intercooler F. From here it passes to the pipe *c* to the upper end of the cylinder C from which it passes to the third cooler G and from here through the pipe *e'* to the lower end of the cylinder D and from this through the pipe *e* to the final after cooler H, from which it is led through the outlet *f* to the storage bottles. From this it will be seen that the air passes through the upper end of the cylinder A, lower end of cylinder B, upper end of cylinder C and lower end of cylinder D and in its passage between each passing through one or the other of the coolers.

The intercoolers employed are of two different designs, the two coolers for the lower pressures consist of a shell enclosing a nest of vertically arranged cooling pipes through which the air passes going from one cylinder to the other, the coolers for the higher pressures consist of a shell enclosing a pipe coil, the air passing through the coil from one cylinder to the other. In providing a cooler for the lower pressures where great cooling surface is required on account of the large volume of air to be cooled, it was considered proper to provide tubes, but in dealing with the cooler for the higher pressures, coils were substituted so as to dispense with as many joints as possible. The coolers are arranged so that in case a leakage of air from the cooling pipes into the shell or casing that this air rises with the circulating water up to the operating floor of the engine room and is discharged through a sight discharge pipe under the immediate care of the engineer. All the piping from the first air cylinder and through the entire compressing plant is made of copper.

What may be called an auxiliary governor controlled by air pressure is provided to act upon the governor of the steam engine. This consists of a weighted lever which is operated upon by a small piston which in turn is actuated by the air pressure. If for any reason the presure should become excessive the lever is lifted, when it opens a valve admitting air to a device on the governor so designed as to reduce the steam supply and to all practical purposes throttles the engine.

Some idea of the massiveness of the machine may be obtained from the bare statement that it is 60 feet in height. It will be employed exclusively for supplying air to the air motor on the street railway cars. It may be stated that since their first trial several months ago

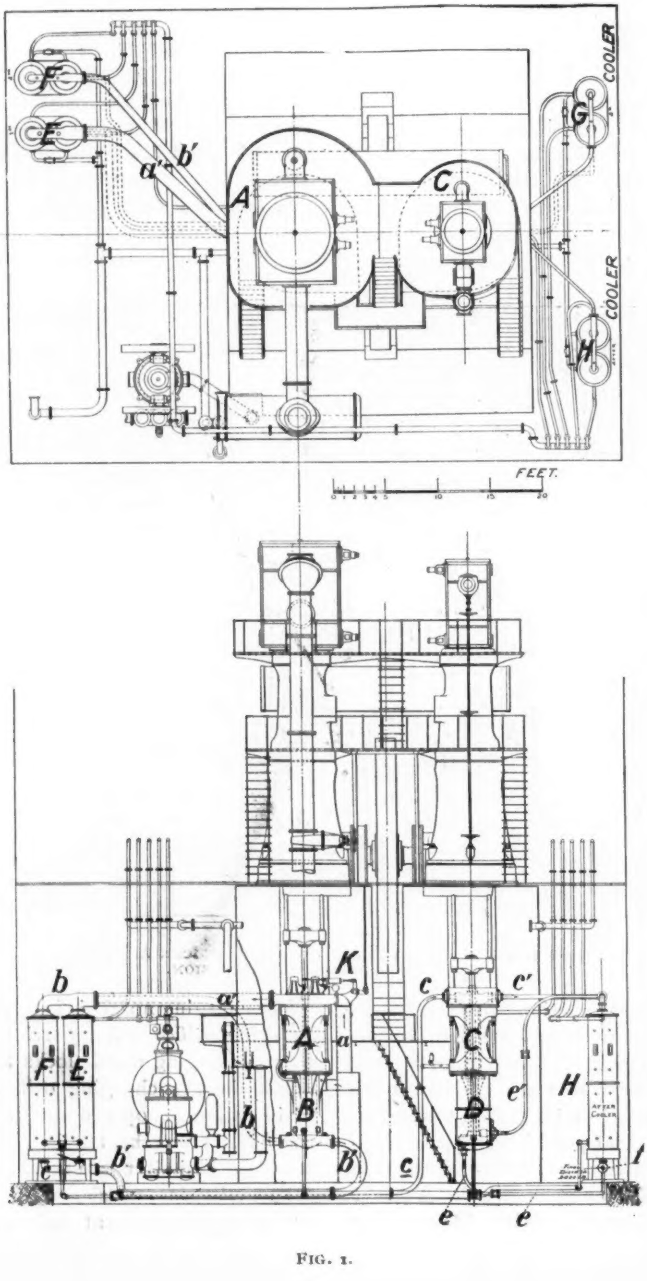
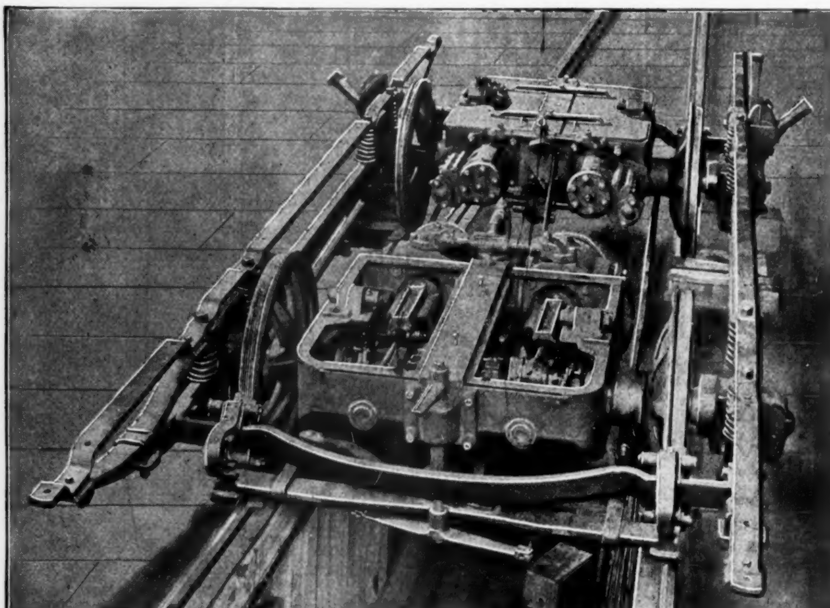

COOLER
G
COOLER
H
F
E
a'
b'
A
C
FEET.
0 1 2 3 4 5 10 15 20
K
b
a'
A
a
c
c'
C
F
E
B
D
e'
H
AFTER COOLER
b
b'
b'
c
c
e
e
f

FIG. 1.

the air motors of the Hoadley-Knight type introduced on the street railroad line have given good results.

Compressed air for the purpose of traction by this system is generated and collected in a manner similar to the manner of generating and collecting gas, and the necessary means for the storing of compressed air at high pressure consist in the collection of numerous bottles connected together in series or manifolds whereby the different sections of storage can be cut out from one another. In the storage system erected at the 24th street compressor station there are about 600 bottles. These bottles are all tested to a pressure of 4,000 pounds per square inch, and are used to store air at a pressure of 2,500 pounds per square inch. There is no wear and tear on these storage bottles other than can be made good by painting from time to time. The storage bottles are connected together with proper pipes and valves and communicate with several charging stands in the car house. The cars can be charged with compressed air at 2,500 lbs. pressure in about two or three minutes' time. The method of connecting the compressed air pipe to the car is similar to the way in which the breach is locked to a gun.



BIRDSEYE VIEW OF THE MOTOR AND TRUCK OF THE AMERICAN AIR POWER COMPANY'S SYSTEM OF STREET CAR PROPULSION.

The charging nozzle is introduced in the charging orifice and a partial turn given to the charging nozzle locks the charging nozzle in the charging orifice, then the main valve is opened admitting air to the car. The reheater is charged with steam in a similar manner.

The charging nozzle of the reheater is provided with a vent hole through the

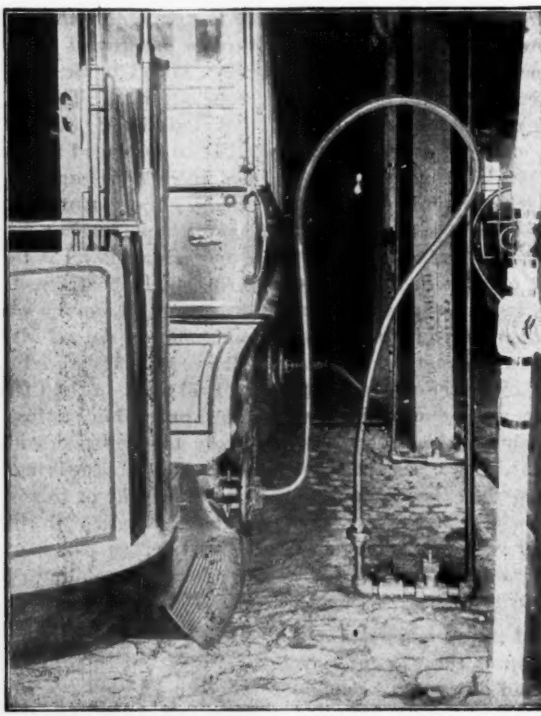
centre whereby the coupling of the charging nozzle to the charging orifice makes communication for the steam to enter the reheater and for the vent to go out from the reheater with the one charging nozzle. In the recharging of the compressed air cars the first operation is to connect the steam charging nozzle to the reheater and then to connect the compressed air charging nozzle to the charging orifice. This operation takes from three to four minutes. These compressed air cars are equipped with six Mannesmann tubes, three on either side of the car under the seats and making a storage capacity of about 45 cubic feet. This storage capacity will enable the car to travel distances of about fifteen miles. The reheater is hung to the car body and lies between the two motors. It is a seamless welded tube and holds about six cubic feet of hot water. The air from the storage reservoir passes by a reducing valve and is reduced from a varying high pressure to a constant normal pressure. A throttle valve is on the other side of the reducing valve controlling the admission of the air to the heater and thence to the motor. When the throttle is opened the air passes through a coil in the reheater and before it enters the reheater a spray of water is introduced into the air and passes through the coil in the reheater on to the motor.

The motors are of the compound type, high and low pressure, the air entering the high pressure and doing work expansively and then passing over to the low pressure motors and doing more work, and then being exhausted to the atmosphere through a muffler to prevent noise. The motors are of the enclosed type, similar to street railway electric motors, and are applied directly to the car axle. They consist of the two high pressure motors four in. in diameter by six in. stroke, and two low pressure motors eight in. in diameter and six in. stroke. Mounted on the crank shaft in the motor is a pinion which engages in a spur gear fixed to the car axle, the reduction is about 2¼ to 1. The motor cylinders are equipped with piston valves which are controlled by a movable eccentric of the wedge type. These eccentrics are connected directly to the crank pins of the motor and the wedges for operating them connect it to a common lever extending across the motor casing, and by means of this wedge eccentric the motor is adapted to run in the forward or backward motion and any degree of cut off for the control of the motor can be obtained. This valve mechanism is connected directly with the throttle valve and is so arranged that the motor man in managing his car has but one lever to control. The motor casings are partially filled with oil, so that when the motor is in operation the oil is thoroughly broken up in small particles, thereby properly lubricating all moving parts. These cars are the standard of the Metropolitan Street Railway Co. They are built on the standard Brill truck of eight feet wheel base.

The application of these compressed air motors to street cars is similar to the application of electric motors, that is to say the weight of the motor is partially on the car axle. All the other parts of the system, as the storage bottles and the reheater, are mounted to the car body and all under the effect of the car springs.

The Mannesmann bottles are all tested to a pressure of 4,500 lbs. per square inch, and as they are filled with air at a pressure of 2,500 lbs. per square inch, there is a factor of safety of about 2. The question is frequently put as to the liability for these tubes to explode. When the tubes are filled with the air at 2500 lbs. per square inch there is no practicable way whereby the pressure can be increased, in fact, the only thing that can happen is for the pressure to decrease. This condition is greatly different from any other engineering problem. A bridge is built over a stream or anything else to carry the public

and designed to carry a certain load. Bridges so made do very well but it sometimes happens that they get overloaded and break down. This cannot happen with the compressed air bottle. Should a car collide with another car or something similar the worst that could happen to the bottle would be to squeeze it together a little bit and then it would relax to its normal condition. Possibly one of the small pipe joints might start to break but no serious explosion or destruction is likely to be caused by a collision.



CHARGING APPARATUS FOR AIR AND STEAM. THE STEAM BEING USED FOR RE-HEATING PURPOSES.

Progress in Compressed Air.

Mr. Walter H. Knight, consulting engineer of the American Air Power Co., the International Power Co. and the New York Auto-Truck Co., in discussing the advance to a practical point of compressed air for use as a motive power, says:

"The recent advances made in structural material has enabled us to handle pressures with absolute safety that were not heretofore possible. These air pressures mean a greater mileage of vehicles, so that, where one of the old time vehicles, such, for instance, as the compressed air cars used in Paris, can make but two or three miles from one charge, we are now able to run from 25 to 50 miles without recharging. We can build air cars to-day that will run half a day on one charge, having thus to be charged only at night and at noon.

"The air flasks that hold the compressed

air under several thousand pounds pressure have been rapidly evolved during the last few years, so that now we can produce in this country, without going abroad, nickel steel flasks, not only twice the strength of those formerly used, but which are absolutely incapable of rupturing under the pressure used.

"There is absolutely no more danger in connection with the pressures used than there was, for instance, in electric motors, where the centrifugal force engenders a pressure of over 5,000 pounds per square inch in the armatures and commutators. This is evidenced sometimes by commutators distributing their commutator work on the roof of the car. In fact, the flasks are much safer, because the pressure is always definite, and not dependent upon some variable factor like centrifugal force, speed, or as in the case of a steam engine, low water, hot fire sheets, etc. The air pressure is a cold pressure and can never exceed that which is given it by the compressor, which itself can go no higher than a certain point and is just as fixed and absolute as is the strain upon the cables of the Brooklyn Bridge. It is always in this, as in other cases, a question and factor of safety. The Brooklyn Bridge would be a very dangerous structure if the cables were not strong enough. If they are, it is safe.

"Quite as important as the question of air reservoirs in bringing the air motor out of the impracticable into the practicable field was the question of heating, which has now been improved to such a point by the use of hot water in connection with the air, that more than double the effect is obtained from the same amount of heat as was done two years ago. This, together with the simplification of the motors to a point where they are scarcely more complicated than an air brake, enables us to produce an air vehicle that fulfils every requirement of an automobile. These vehicles may be charged instantaneously instead of requiring six hours, as in the case of a storage battery; their reservoirs are of unlimited durability instead of being susceptible to the rapid depreciation that affects the storage battery. They have only one-half the weight of a storage battery and, in common with the latter, possess an entire freedom from any æsthetic objection, such as exhaust, odor or noise.

"Analysis shows that only the stored powers are suitable for automobile work in cities. All prime powers have some one or more radical objections from an æsthetic or practical standpoint. Thus the gasoline or gas motors, when you come to have vehicles of any size, have a very objectionable odor. Even the smaller ones are disagreeable enough. Moreover, vehicles of this type lie down and die when they come to grades, even worse than do the storage battery ones, whereas air motors can be used on grades as steep as 20 per cent.

"There is no danger of injuring the reservoir by a sudden draught upon its power, nor is there any injury accompanying the total exhaustion of the reservoir. For street cars, it does away with all appliances along the line, such as trolley wires, underground connections, cables, etc., and requires only a good roadbed. For long distance work, such as now handled by steam locomotives, it offers on the one hand a stored power not limited by fire box or heating surface, and not requiring dangerous, inconvenient and expensive third rails or trolleys. It further offers an economy much superior to that of the steam locomotives, on account of drawing its power from a stationary engine, which, as is well known, produces power for about one-sixth the cost of that produced by a steam locomotive.

"We are in the air business at the birth of a gigantic industry (as we were fifteen

years ago in the electric business), that will reach out into every field of power and bring about economies and simplifications that the much-vaunted electricity is incapable of realizing.

"For truck work, where tremendous power is required, with minimum weight and absolute reliability, there is no other force that I can see that comes anywhere near it. Our trucks for carrying 20,000 pounds weigh only 8,000 pounds. They are made of steel only and are as durable pieces of mechanism as any that I know of. They can run at an expense not exceeding ½c. a mile for power, and with instantaneous charging at numerous substations can cover any desired distance. Even with one charge, they can make an ordinary trip in the Metropolitan district with a maximum load."

Railway Era.

Air Power Cars in Chicago.

The first trip in Chicago of a car operated by compressed air was made the evening of May 12 over the tracks of the North Chicago street railroad company between the limits barns and Washington street. The run was made in place of the first "owl" car. The experiment was so successful the company will supply at once all its north side lines with similar cars in place of the horse cars which now make the night trips.

People who caught the compressed air car were surprised to find themselves at the limits barns in twenty-five minutes, including a stop of five minutes at the Elm street power house. The car proved capable of any speed desired, ran without noise, and was under perfect control.

Robert Hardie, inventor of the car, was the engineer, and Otto Berthold collected the few fares. The passengers were mostly officials and others interested in the test. Henry D. Cook and A. C. Soper, officers of the Compressed Air Motor Company, were among them. The actual running time from the Elm street power house to Washington street and return to the limits barns was twenty-eight minutes.

Machine Shops and General Manufacturing Purposes

Portable Pneumatic Riveters in Ship-Building.*

By W. J. Babcock, Member

Probably the hardest manual labor in all the various operations in building a ship is that of riveting. Combined with this is an amount of technical skill acquired only by long and arduous apprenticeship at the trade, and varying with the class of rivets driven. Like the stonecutter who can only learn to do first-class work on one particular stone, and is at a loss, for instance, on marble, if trained to granite, so a first-class shell riveter cannot properly drive inside rivets, and vice versa; while the boiler riveter, however good he may be at his own work, is of little use on any part of the ship's hull. With such conditions, a difficult trade to learn, a hard and exhausting one to follow, wearing a man out in his youth, for no one ever saw an old riveter—although in other trades age itself is not necessarily a bar—wages are inevitably high, and most of the work is done by the piece. When the work is to be had, therefore, the riveter makes a great deal of money, but at the expense of his vital energies, which he is too apt to attempt to restore by stimulants, especially as his work is done almost entirely, from the nature of the case, in the open air, exposed to the heat of summer and the cold of winter.

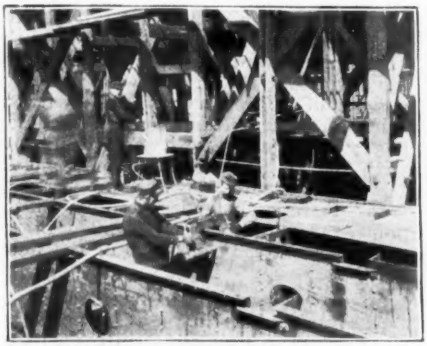
The tools with which he works are furnished entirely by the yard, so that, unlike other mechanics, he is not obliged to have anything of his own, while, as rivets are rivets the world over, little familiarity with the customs of any particular yard is required of him, and he has not much incentive to remain in one place to establish relations of amity and mutual esteem with his superiors.

The riveters, therefore, have been extremely independent, arrogant, and high-handed in their relations with the masters, giving more trouble than all the other classes of labor in a yard put together.

* Read at the Fortieth Session of the Institution of Naval Architects.

In addition to this the rapidly increasing size of ships, with the corresponding necessity for heavier plating, doublings, etc., requires the use of larger and longer rivets, which cannot be properly closed down by hand, however skilful or willing the men may be.

For all these reasons, in the yard of the Chicago Shipbuilding Company, of which I am the manager, some three years ago a determined effort was begun and an extended series of experiments entered upon to develop machinery capable of being operated by unskilled labor, by which all the rivets in a ship could be driven, which effort has been entirely successful, so that in the last ship we have completed there were a little over 250,000 rivets so driven out of a total of 340,000. But for insufficient air supply the proportion would have been greater. The decision to use compressed air for the operation of the machines, instead of hydraulic or electrical power, was made for several reasons. The severe winter climate of Chicago is against the use of hydraulic machinery in the open air, besides which we were aware that hydraulic compression riveters had never made much headway in British yards, though long in the market, and it seemed wiser to try a new line. Electricity, although advancing by leaps and bounds, is an intricate science in itself, with which we are not familiar enough to see much promise in it, and all electrical appliances are very costly and somewhat delicate, apparently unsuited to the rough handling inseparable from ship work.



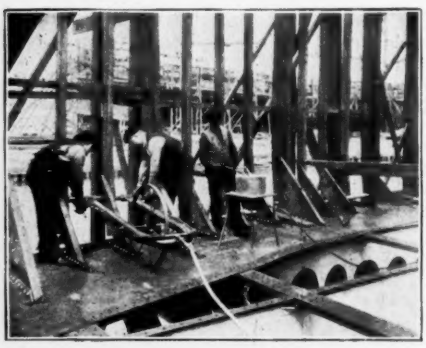
SMALL YOKE RIVETER.

More important, however, was the fact that air can be used for chipping and caulking hammers, for drills and reamers, and for hoists, as well as for ventilating and cooling confined places, so that a compressing plant is a necessity in any event, while we, of course, knew that pneumatic compression riveters are universally used and indispensable in American bridge shops.

We had in use already at that time a stationary steam riveter of the ordinary type driving rivets in such portions of the ship as could be assembled and handled as a whole. 1800 rivets is an ordinary day's work of ten hours on this machine, at a cost of one-half cent apiece. A very short experience with compression riveters showed that their great weight —reaching over 2500 lb. for 6ft. gap— interfered too much with facility of handling to make them either useful or economical. We then turned our attention to the pneumatic hammer, consisting of a cylinder in which a piston reciprocates, delivering an almost continuous series of blows against the end of the chisel, caulking tool, or rivet die. The hammer is light, powerful, short enough to go between frames, and small enough in diameter to get at rivets in corner angle. For small rivets it can be held in the hand, though the work is severe. It is however, almost impossible to hold on to the rivet by hand, the heavy holding-on hammer being fairly jarred off the head of the rivet by the rapidity of the blows from the pneumatic hammer, giving the holder-on no opportunity to bring his tool back into position between blows as in hand riveting.

We quickly devised a simple pneumatic holder-on, however, which admirably serves the purpose, consisting only of a cylinder carrying a piston, behind which air is admitted, the rod extending through the front head and being cupped out to go over the head of the rivet. A piece of pipe secured to the cylinder braces it against any convenient support. Combining these two machines with a yoke, the hammer being mounted on one arm and the holder-on on the other, makes a self-contained machine in which the yoke itself can be made very light, as it has to resist only the pressure of the air against the end of the holder-on cylinder and the reaction of the hammer blows.

Various sizes of these yoke riveters are used, and the weights are as follows for the depths of gap given, the yoke being made of pipe for the larger sizes:—9in., 83lb.; 51½in., 160lb.; 70in., 220lb. It is very evident, therefore, that these riveters are portable in the highest degree. In fact, in the greater number of places they are moved about by two men entirely by hand, the cross-bar in the throat of those of larger gap forming a slide, and assisting in the movement. Occasionally they are suspended on a trolley from a light framework of pipe. A variation of the device is to mount the hammer in a cylinder as a piston, behind which air is admitted to force the hammer forward as the rivet point is beaten down, the die on the opposite arm of the yoke being then solid, and may be small to get into contracted places. For driving the rivets connecting frames and brackets at the tank top of a double-bottom ship the yoke is mounted on a pair of rough wooden wheels for ease in handling.



YOKE RIVETER.

The above descriptions will, I trust, sufficiently make plain our methods for all rivets which can be reached on both sides by a yoke or gap riveter. There remain three classes of rivets in a ship, as follows:—(1) Those through decks and tank tops, mostly countersunk, and all driven vertically downwards from above; (2) bulkhead rivets—other than those near the top, or adjoining openings, which can be reached by a yoke—nearly all with full heads; (3) those in the outside shell of the ship, all countersunk. These three classes must be reached by riveters on one side and holders-on on the other, without any connection whatever between them.

The first class are most easily driven, and for them the hammer is mounted on a bent pipe, with a pair of wheels at the bend. The operator raises a handle to bring the flat die on to the rivet, and, the bend of the pipe being loaded with lead, has only to bear down upon it in driving. A second man, with a pneumatic chipping hammer, cuts off the surplus metal, and, the riveting hammer being brought back, a few seconds complete the operation. In this case the pneumatic holder-on is operated from below by a third man, being braced against the bottom of the ship or the next deck below. For the second class, the hammer is fastened to the end of a wooden beam which slides freely on a supporting stud bolted to the bulkhead, an adjustable rod at the other end governing the distance of the hammer from the rivet point. A large number of rivets can be reached without shifting the stud. It is necessary, of course, to use the form of hammer described above with the air pressure behind it, and, as the die is cupped out to form the snap point, there is no tendency to slip off the point. The holder-on is mounted in the same way on the other side of the bulk head.

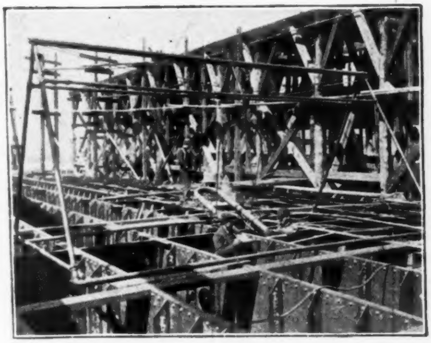
We now come to the third class, or shell rivets, which in many respects are the most important rivets in the ship, requiring the most careful workmanship and the best finish. It is evident, at the start, that the varying thicknesses of plates, frame flanges and liners, and especially the depth of countersink, render it impracticable to so gauge the length of rivet used that there will always be just enough metal to properly fill the countersink and finish the point, and that, therefore, as in hand riveting, a longer rivet must be used, and after the point is beaten down with the surplus metal crowded off to one side, this surface must be chipped off, and then the point finished up, rounded slightly, and any seams between the rivet and the plate driven together and closed. To do this a certain amount of freedom of motion must be allowed in the hammer, so that its axis may be inclined at a slight angle in any direction with the axis of the rivet itself. This result is attained by mounting the hammer

in gimbals on the end of a bar, instead of its being immovably fastened to it, as in the bulkhead riveter. For bottom rivets this bar is attached, by a central bolt on which it revolves, to a trolley running inside a slotted piece of pipe, which is either bolted to the bottom of the ship or held up against it by a simple pneumatic jack at each end. The bar carries at its other end an adjustable brace as in the bulkhead riveter, and there is, of course, an air cylinder behind the hammer to force it in as the point of the rivet is beaten down.

At one setting many rivets can be reached, and the whole arrangement is very satisfactory, a pneumatic holder-on being used inside, and an ordinary pneumatic hammer being used to cut off the surplus metal before final finishing.

It is evident that the freedom of movement of the hammer can be secured in other ways, such as a ball-and-socket joint of large radius, but we have found the gimbal mounting more satisfactory, and all that can be desired. While the same arrangement can be used for the side of a ship, it is not very satisfactory there, and a different one is desirable. In this the bar carrying the hammer is vertical, and is fastened to a bored-out tee, sliding freely on a horizontal pipe. This pipe is prevented from moving away from the ship by vertical pieces of bar or angle iron at each end, bolted to the ship parallel to the side and 8in. or 10in. away from it. The pipe is hung from pulleys above, and counterweighted so that it moves freely up or down. By the vertical movement of this pipe and the horizontal movement of the sliding tee any rivet can be reached from the gunwale of the lower turn of the bilge, and for a length of about 10ft., without shifting the rig. Inside the ship a couple of rough wood stanchions are bolted or wedged in position for guides, and a counterweighted piece of 2in. plank moves against them in unison with the riveter and forms the brace for the pneumatic holder-on, which is easily moved by hand into proper position.

The quality of the work done by all these machines, both inside and shell, is first class in every respect, and far superior to hand work, and such is the unanimous opinion of the inspectors who have been and are on duty in our yard. That this is natural appears from several considerations. The rivets are closed down more rapidly and at a much higher temperature, and, as it is always easy to bring the axis of the hammer in line with the axis of the rivet, and, in fact, natural for the men to so bring it, the rivet is plugged at once by the first blows of the hammer, thoroughly filling the hole throughout, before the point begins to form. The tendency of hand riveters to save labor by forming the point without thorough plugging, leaving a rivet which, though looking all right and passing the tester, is liable to loosen afterwards in service from the constant jar and vibration of the hull, is, therefore, avoided. In many confined places, also, where only one man can strike, and the space for the swing of the hammer is limited to



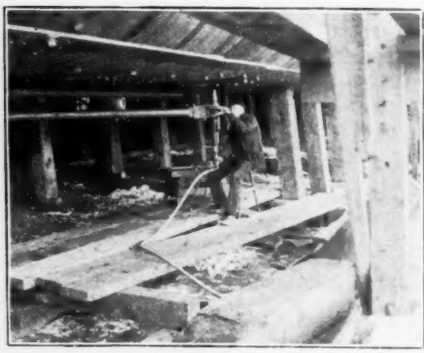
LARGE YOKE RIVETER.

the frame spacing or less, hand rivets are very apt to be poorly driven, but it is evident that such considerations do not affect the machine, and that, if the pneumatic hammer can get to the rivet at all, it is as well put in as in the most open parts of the work.

As to the cost of the work, I submit the following figures, from the last ship completed in our yard:—

Inside Rivets.—All ¾in.			
Hand, piecework..	25,073	Av. cost,	3.16c
Hand, day work..	9,255	"	8.57c
Air................	151,167	"	2.06c
Steam (Fig. 1.)...	23,544	"	0.51c
Shell Rivets.—⅞in. and 1in.			
Hand, piecework..	51,306	Av. cost,	3.99c
Hand, day work..	4,314	"	7.69c
Air................	74,493	"	2.96c

The amount that should be added to the machine cost to cover interest, maintenance of plant, and operation of compressor, is undoubtedly much greater than the corresponding amount for hand riveting, which is little beyond hammer heads and handles; but I cannot give it exactly, as we were using much air at the same time for drilling, reaming, and caulking, as well as for blowing the rivet-heating forges—so much so, in fact, that we exceeded the capacity of the two compressors in use, and not only had to stop putting on more machines and go back to hand riveting, but, for a large portion of the time could not maintain more than 70 lb. pressure in the air mains, which seriously impaired the efficiency of the hammers. We had an air capacity of



BABCOCK-GUNNELL SHELL RIVETER.

about 850 cubic feet of free air per minute at 100 lb. pressure, but we have now nearly completed a new compressor of 3000 ft. capacity, to work at 125 lb. pressure, and anticipate much better results hereafter. It is only fair to call attention to the fact that most lake freight vessels, like the one referred to above, are of very full model, with a large number of frames exactly alike amidships, and that they are launched broadside on, and therefore stand level on the stocks, both of which conditions are favorable to the use of these machines, especially of the shell riveters. Against this, however, it is equally proper to state that much of the development of the inside riveters took place on the boat referred to above, and that the shell riveters had never been tried at all until they commenced on her bottom plating. In the latter case, therefore, all the experimenting and working out of the appliances for rapidly and economically handling the machines, as well as breaking in the men to use them, came on that boat, and the cost appears in the above statement. It must be remembered also that the men who have worked all these machines are not riveters, nor even mechanics, but only laborers, and were not on piecework.

The largest rivets we have as yet driven with these machines are 1in. in diameter. But there is no reason whatever why larger sizes cannot be driven with equally satisfactory results. It is only necessary to use a larger hammer, one of greater diameter and longer stroke. In gasometer work in America this has been done already with gap riveters and 1¼in. rivets closed with perfect success, and there can be no question but that a larger size shell riveter will handle rivets of equal diameter with the same facility, the somewhat greater weight of the machine being no disadvantage, as it is counterbalanced and does not come upon the operator at all.

In Chicago we are still experimenting with and developing these tools, and hope to much further increase their efficiency and economy. I have thought, however, that the members of the institution might be glad to know of the results already accomplished in a matter of such importance to shipbuilding.

Pneumatic Dispatch

The Pneumatic Mail Tube System.

J. FOSTER SYMES *

The system by which matter is transported through closed tubes by means of a current of air therein, is not a new idea by any means, though its successful application for commercial purposes is of recent date.

The earliest ideas of pneumatic transportation are found in the records of the

* *Yale Scientific Monthly.*

Royal Society of London. Here we learn that Denis Papin sent to the Society in the seventeenth century an article on the "Double Pneumatic Pump." He exhausted the air in a long metal tube, causing a piston to move through it, which drew after it a carriage attached by means of a cord.

It was not, however, until 1853 that the first successful pneumatic tube system was built in London. A one and one-half inch pipe was laid between Founder's Court and the Stock Exchange. Its length was 650 feet, and the carrier was propelled through it by means of a vacuum created by an exhausting engine at one end of the line. The roughness of the interior of the iron pipes caused much trouble, and in 1858, when the system was extended, two and one-half inch tubes made of lead were used, the carriers being made of gutta percha with an outer lining of felt.

From this small beginning the London system has grown rapidly and now comprises forty-two stations, connected by thirty-four miles of tubes. The latter are made of cast iron with a lining of lead, and vary in diameter from two and three sixteenths to three inches. The lines are laid out radially, and the air exhausted at one end, and compressed at the other. This system has been adopted in Liverpool, Birmingham, Manchester, Dublin and Glasgow. Experiments were also made in London with an underground pneumatic railroad. In 1863 one was built eighteen hundred feet in length and two feet eight inches square. A second was constructed in 1872 from the Post-office to Euston station, a distance of two and three-fourths miles. This one was somewhat larger than the first, being four and one-half feet wide by four feet high. These tunnels were operated by means of fans, which forced air into one end and exhausted it from the other. They were never a success, however, and were soon abandoned.

In 1865 a system of pneumatic tubes for the transmission of telegraph messages was built in Berlin. Wrought iron pipes, two and one-half inches in diameter, were laid in pairs, one being used for sending and the other for receiving messages. The tubes were connected at one end by a loop and a steady current of air kept up by means of a compressor at one end and an exhauster at the other. The system now in use there, however, is somewhat different, the power being supplied by large storage tanks containing compressed air. There are altogether thirty miles of pipe and thirty-eight stations in the city.

The Paris pneumatic system has been in operation for many years and most of the branch post and telegraph offices are connected with each other by it. A novel method of compressing the air is used, for instead of employing a steam engine, it is compressed in tanks by displacement with water. The diameter of the tubes now used in Paris is 2.55 inches. The carriers are sent out in trains of from six to ten, and are propelled by a leather covered piston at the rear which fits tightly in the pipe.

In 1867, at the American Institute Fair held in New York, the late Alfred Beach exhibited a pneumatic tube railroad. A car, holding ten people, ran on a track laid down within a circular wooden cylinder which was about 100 feet long and six feet in diameter. A current of air was supplied by a large fan, running at the rate of two hundred revolutions per minute. He later built a tunnel under Broadway, near Warren street, extending a distance of two hundred feet. The car was driven by a large rotary blower in an adjoining building, and could be made to go in opposite directions by simply reversing the valves of the blower. Mr. Beach also designed a system of pneumatic tubes to convey mail from the street boxes to the postoffice. The letters were to be delivered into cars from revolving hoppers, which were made to turn by pins on the car hitting the vanes, the carriages being propelled by a current of air. He also, a few years later, built a line over one thousand feet in length with a very smooth interior. This pipe led to a large receiving box connected with an exhausting engine. A letter dropped into the pipe at any point was carried along by the current to the box, where it fell to the bottom, from which it could be easily removed.

For many years the pneumatic tube has been a common means for the transmission of cash, etc., in large stores. The Western Union Telegraph Company, several years ago, connected a few of its offices by a pneumatic system, but the first real attempt to introduce it on a large scale into this country was made in 1893 in Philadelphia. A six inch main

was laid to connect the main postoffice with the Chestnut street branch, a distance of nearly a mile. On account of the large size of the pipes compared to those used in the European system, the capacity of this plant was much greater. The area of the tubes was increased many times, and of course the carriers were correspondingly larger. The speed of the Philadelphia system was moreover doubled and had improved appliances for receiving and transmitting. This plant was opened in 1893 and has been operated successfully ever since.

When in 1897 the tubular Dispatch Company of New York was authorized to construct a pneumatic tube system for the transmission of mail between the General Postoffice and some of the branch stations, all the different plants then in use were inspected. After careful investigation the company decided to copy after the Philadelphia line, which had proven so successful, and plans were accordingly drawn for a system running from the postoffice to the Grand Central Station, the Produce Exchange, and to Brooklyn, over the Bridge. The first line to be put into operation was the one running to the Produce Exchange, which was opened in the fall of 1894. The others have since been completed, or will be at an early date.

The company determined to make the tubes of larger capacity than those used in Philadelphia, and to maintain a working speed of thirty miles an hour under a headway of twelve seconds. The line to the Produce Exchange is nearly four thousand feet long and consists of two tubes, side by side, eight inches in diameter, and about five feet below the surface. One is used for outgoing and the other for incoming mail, they being connected at the sub-station by a loop. A powerful compressor forces the air into the outgoing tube at a pressure of seven pounds to the square inch. On account of its elasticity, it flows through the pipe with an increasing velocity, but by the time it reaches the sub-station the pressure has fallen just one-half. From here the current returns by the second or return tube, and as it enters the receiving tank its pressure is equal to that of the atmosphere. This tank is joined to the suction pipe of the compressor, and as the two lines are connected by a loop at the other end, there is a continual circulation of air throughout. The pipes are of cast iron with a very smooth interior finish. All bends are of at least eight feet radius and made of seamless brass with a diameter of not less than eight and three-fourths inches on the inside.

The carriers are made of thin steel plates rolled into a cylinder, riveted and soldered. They have two bearing rings of packing, one at each end, which fit the tube and prevent any air getting by, causing it to move with the same velocity as the current. The shell proper is about two feet long and seven inches in diameter. The front end is concave and has a filling of felt which protects it from any shock it may receive. The rings form the sliding contact and keep the shell proper from touching. The carriers are closed by a hinged door at the rear, which is so arranged that it cannot open while in the tube.

The current is continuous from the starting of the compressors in the morning until they stop at night, so it was necessary to have some means by which the carriers could be inserted and removed from the line without interfering with the flow of air. This is done by means of a transmitter and receiver, one at each station. The former consists of a piece of eight inch pipe, long enough to enclose the carrier. It is hung on a shaft, overhead, so that it can be swung out from the main line to receive the carrier and then moved back into position where the current forces the latter into the main tube. The ends are smoothed off square so that no air can escape at the joints. When this section is swung out of line two projecting plates move across the ends of the opening and shut off the air, the current meanwhile going around by means of a connection. When the transmitter is not in use the movable section is drawn over to the loading tray and the air goes through the U shaped by-pass. When a carrier is to be sent it is placed in the tray and pushed into the transmitter, then, by pulling a lever, the latter is swung into position and the carrier is forced out. An automatic time-lock prevents them being sent with less than twelve seconds headway, thus ensuring a proper distance between them in the tube. When the carriers arrive at the sub-station the pressure of the air is three and one-half pounds to the square inch, so the tube cannot be opened to remove them. They

also have a velocity of about thirty miles an hour, and some means had to be provided for gradually checking their speed. These two things are accomplished by means of a closed receiver which consists of an eight-inch cylinder four feet in length. In its normal position it forms a continuation of the tube by which the carrier arrives, and on entering the receiver it compresses the air in front and is stopped without any shock. There are a number of openings in the pipe just in front of the receiver connected with the other or returning line by which the current continues back to the main station. The compressed air in the receiver opens a small valve and thus keeps the carrier from being thrown back into the main tube. The receiver is automatically discharged in three or four seconds by a piston, which tilts it to an angle of forty degrees. The carrier slides out onto an inclined platform which is kept in position by a counter weight. The weight of the carrier, however, overbalances this and causes it to drop to a horizontal position, and the carrier is thrown out onto a table in front of the operator. This piston is worked by compressed air supplied from the receiver. Above the front end of the receiving chamber is a plate, arranged so that it comes down and closes the end of the main tube when the receiver is tilted to be discharged.

The transmitters at both ends of the line are the same, but the receiver at the main office is very different from the one at the sub-station, which is described above. At this end it consists of a section of the end of the tube closed at the rear by a gate. The air, now expanded to the same pressure as the atmosphere, passes from the tube through openings, four feet in front of the receiver gate, down to the tank in the basement. The momentum of the carrier is checked in compressing the air in the chamber after it has passed these openings. Part of this compressed air operates a piston which opens the gate mentioned above, then the small pressure of air forces the carrier out onto the receiving table. If there is not sufficient pressure to expel it, the openings can be partly closed by means of a valve. As it passes out, it hits a small finger which causes the gate to be closed.

These, in brief, are the main features of the pneumatic tube system. Improvements are continually being made in the line of quicker handling and greater capacity, and now that it has been proven a success there is every prospect that it will come into general use in all large cities for transmitting mail to the various sub-stations. Plans are now being considered by the postoffice department to further extend the present lines in New York, as well as in other cities.

Signaling and Switching

Pneumatic Interlocking.

It has been the custom for many years to operate the switches and signals of large and important track systems from a central point, in order that greater economy and efficiency in train service might be secured than was possible under the primitive method originally employed, which entailed the use of many men moving continuously from switch to switch, and a diversity of hand signals and targets that, to say the least, were confusing and oftentimes misleading to enginemen.

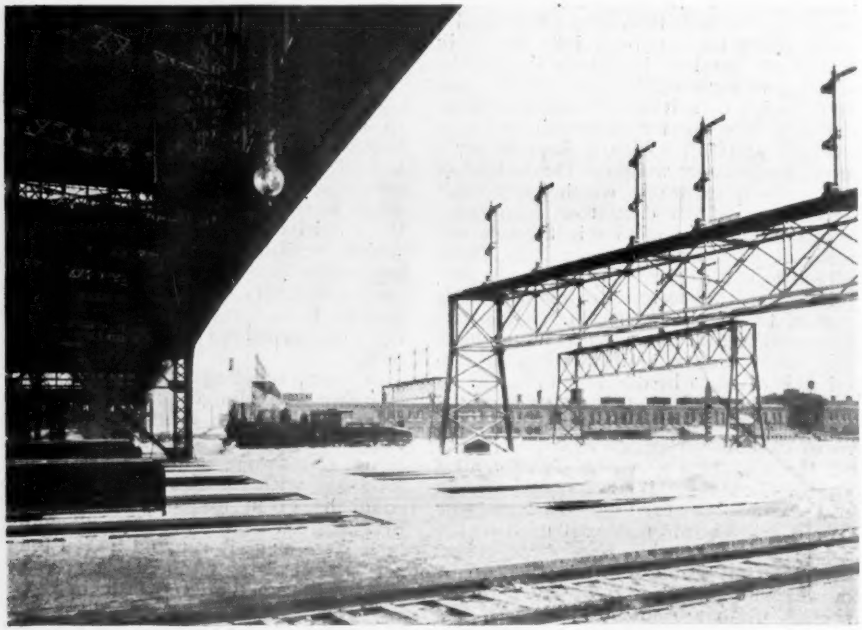
In concentrating the operation of switches and signals, an important adjunct to their safe operation, heretofore impracticable, became possible; switch and signal levers were readily made to interlock one with another so that a signal could be given for a train to proceed over a given route only after all switches in it were securely set and locked for the safe transit of the train over them. Conversely, a signal giving a train right of way over a route, locked against operation all switches in it until the signal was withdrawn. This method of operating switches and signals is known in railroad vernacular as an "Interlocking." The apparatus by which they are moved is termed an "Interlocking Machine," and the structure in which it is located, an "Interlocking Tower."

The levers of an interlocking machine are usually mounted in a cast iron frame secured to the framework of a tower, and are massive affairs connected with the switches by one-inch pipe lines, which are moved longitudinally by the levers in

suitable guide rollers or pipe carriers arranged to support them at short intervals upon suitable foundations, carefully set as to alignment. Signals are likewise operated, frequently, but more generally by means of heavy iron wires suitably supported in anti-friction carriers upon stakes or iron straps extending from the pipe line supports.

However carefully applied and however well designed the appliances of such a system, it is found entirely impossible to operate from a single lever, in large plants, all of the devices that are permissible of such operation, owing to the excessive load they would present to the operator if thus connected. It, therefore, is customary to perform by the operation of two, three, four, and occasionally five levers the work that could be performed by a single one were the operator's power unlimited. When this fact confronted the man who virtually made the hand brake a "5th wheel" on passenger coaches, by adapting compressed air, in the hands of one man, to the duties formerly performed by the muscular energy of several, it is not surprising that his attention was turned toward relieving the labor and expediting the manipulations performed in interlocking towers.

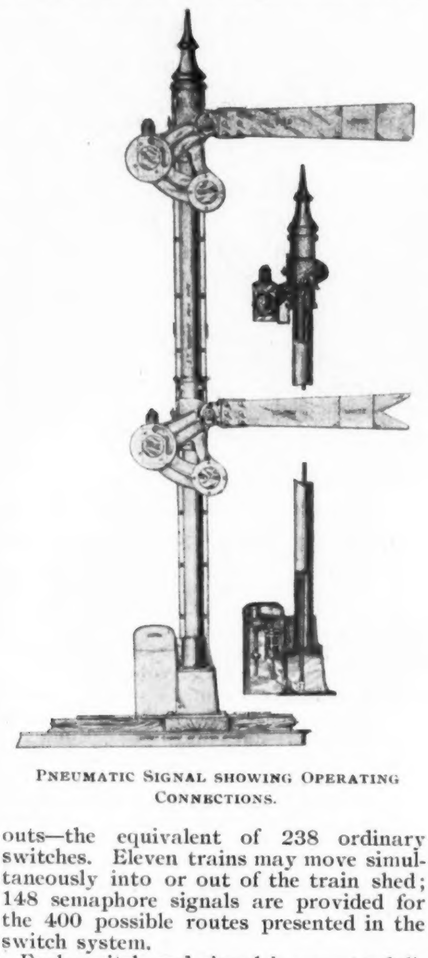
With the experience that brought the air brake to its present state of perfection as an encouragement to the undertaking, the development of the Pneumatic Interlocking System was begun by Mr. George Westinghouse, Jr., in 1881, as president of The Union Switch & Signal Co. of Pittsburg, Pa.



BOSTON SOUTHERN STATION—WESTINGHOUSE INTERLOCKING SYSTEM DURING FEBRUARY (1899) STORM.

After years of laborious and costly experiments, and notwithstanding a very general distrust of the system during its experimental stages, its development was carried through successfully, and to-day it is the system employed at the leading terminal stations in this country and at

many minor places. Its introduction at the new Southern Station in Boston has been attracting widespread interest at home and abroad, chiefly because of the magnitude of the station itself, but largely because of the great area and facilities of its track system and of the complexity of the interlocking necessary to handle it. The tracks included in the interlocking system contain 31 double slip switches, 31 pairs of movable frogs and 52 turn-



PNEUMATIC SIGNAL SHOWING OPERATING CONNECTIONS.

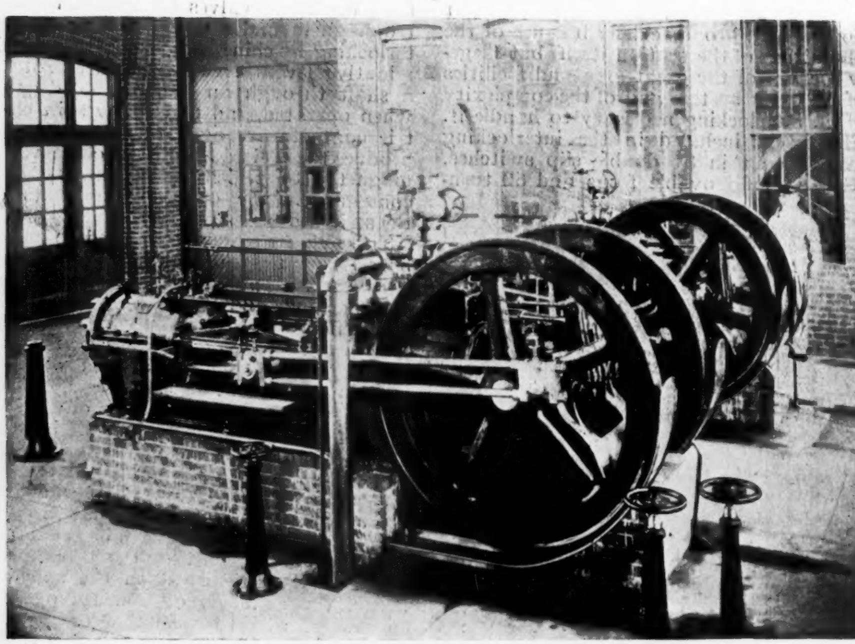
outs—the equivalent of 238 ordinary switches. Eleven trains may move simultaneously into or out of the train shed; 148 semaphore signals are provided for the 400 possible routes presented in the switch system.

Each switch and signal is connected directly to the piston of a pneumatic cylinder secured to its support; each cylinder is provided with a valve controlling the admission and discharge of air to and from it. These valves are shifted by electro-magnets under the control of the interlocking machine which consists of diminutive levers each arranged to rotate a shaft through an angle of 60 degrees when operated, and to thereby shift electric contacts arranged thereon so as to produce the desired conditions of the valve magnets (to which they connect) and consequently the desired movements of the switches and signals.

These shafts are also adapted to move bars lying at right angles to and above them, which extend from end to end of the machine, and which by a system of "cross locks" are made to interlock one with another in the manner customary in other and earlier types of interlocking machines. The extremities of these shafts are engaged by the armatures of electro-magnets which are controlled by the switches or signals operated, and which are so actuated and controlled by the latter that the levers and the devices operated by them must coincide in position before a clear route can be produced.

A miniature model of the track plan is mounted vertically upon the machine frame, the switches of which move to correspond with those in the yard as the levers are operated, and give at all times a correct representation of the track connections.

The signals are mounted generally upon iron truss bridges, 9 of which are used for their support at the new station. They are of what is termed the "Semaphore" type, consisting of an arm or blade pivoted to a post and extending to the right as viewed by enginemen approaching it. When horizontal this arm signifies danger and is so held by a heavy counterweight normally. When declined 60 degrees from the horizontal it signifies safety, and is thus moved, in this system, by action of the compressed air upon the piston of its operating cylinder. This arm carries two colored glasses: a red one before a lamp at night is displayed when at danger and a green one when at safety. From Fig. X a better understanding of this device may be had. The electro-magnet M is in direct control of the interlocking machine. When de-energized its armature is held from the magnet by the spring S and the action of the compressed air upon the valve stem E, formed by the



COMPRESSORS IN POWER HOUSE

rod extending from the armature into the valve chamber. The pin valve P is likewise held seated by the same forces, shutting off the escape of the air from chamber C to chamber C', the latter being normally connected through the open valve E with the atmosphere, as is also the signal cylinder port S P.

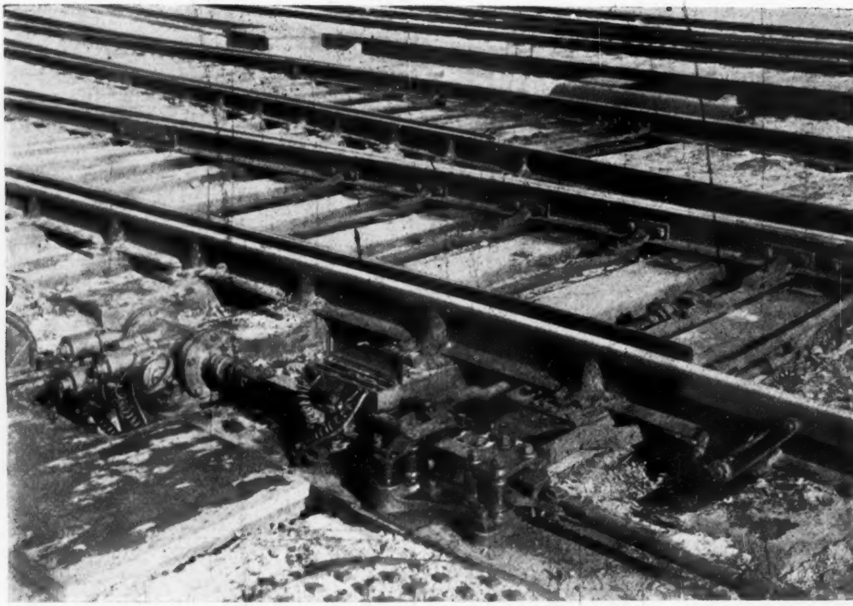
When the magnet is energized the valve stem E is depressed closing the exhaust port E P and opening the pin valve P so that the pressure is permitted to enter chamber C' and consequently the cylinder of the signal, the effect of which is to cause the piston to be depressed and the signal operating rod to be elevated, with the result that the counterweighted end of the signal is likewise elevated and the blade lowered to safety.

When the magnet is de-energized the valves assume their normal positions and the air escapes from the signal cylinder, the signal moving by gravity back to danger.

The switch cylinders are double acting and therefore require two such magnetic valves, one controlling the pressure at one end of the cylinder and one at the other.

Owing to the large volume of air used in the larger cylinders of the switches, these magnetic pin valves do not give direct admission and discharge of the air to and from the cylinders, but control small auxiliary cylinders which shift a D-valve capable of more readily controlling the pressure to and from the switch cylinders.

This D-valve is further provided with a plunger which engages it and prevents its movement unless the plunger is first withdrawn. The withdrawal of this plunger is effected by a third magnetic valve and auxiliary cylinder and the three magnetic valves are controlled by three separ-



PNEUMATIC SWITCH MOVEMENT COVER REMOVED.

ate wires extending from them to contacts of the interlocking machine.

The D-valve lock is a precautionary device entirely and is introduced simply to remove as far as possible the likelihood of a false operation of a switch from unusual conditions and from extreme neglect to properly maintain it in normal order.

The switch cylinder operates with an 8-inch stroke a specially designed movement which gives motion to the switch during the forepart of its movement and locks it in position during the last part of it. It also gives motion during its entire stroke to a bar pivotly mounted along the outside of the switch rails that is known as a "Detector Bar," and which is designed to prevent the movement of a switch under a train passing over it, or standing upon it. This bar rises immediately above rail level at the beginning of the piston stroke and before the switch is moved at all; a train upon the switch rails prevents the elevation of the bar and consequently the movement of the switch.

Under each switch cylinder is placed a cast iron reservoir directly connected with the main pressure pipe of the system; from the reservoir an armored hose connection extends upward to the switch valve and forms an elastic medium through which the valve is supplied with compressed air, thus avoiding all risk of injury to the pipe fittings and valves due to change of track alignment, and to the vibration of trains passing over the switches operated.

The compressed air is generated in the Terminal Company's power house by one or the other of two Ingersoll Piston Inlet Compressors of 14 in. diameter and 18

in. stroke, each capable of pumping 150 cubic feet of free air per minute—an amount vastly in excess of that required for the interlocking system, but an amount of great value in the event of an emergency that momentarily might exhaust the sup-

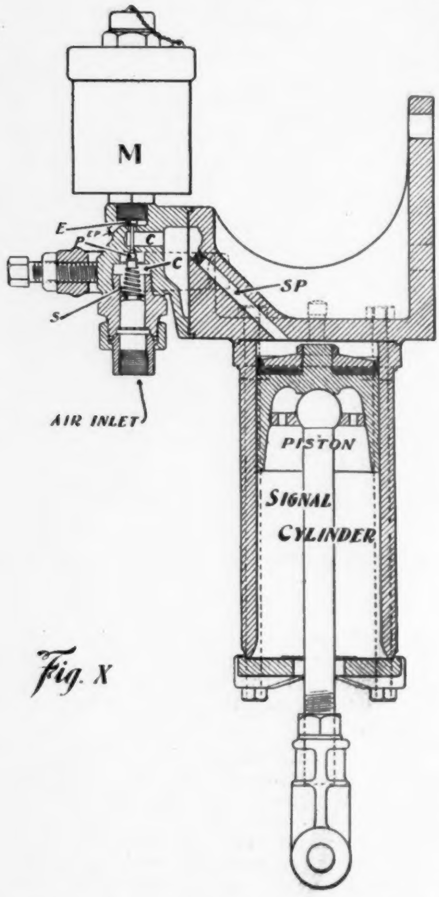
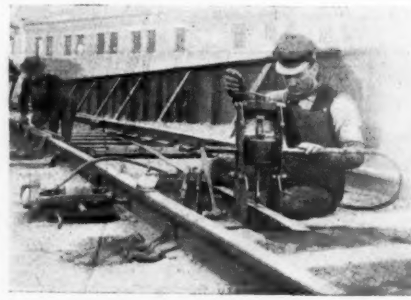


Fig. X

ply in storage. These compressors are therefore running at their minimum speed, about 30 revolutions, instead of at 120 revolutions, their maximum speed,—normally. Each compressor discharges the air as compressed into receiving tanks from which it is conducted to a third receiver before passing through a system of manifold pipes of large radiating sur-



DRILLING DETECTOR BARS BY PNEUMATIC PRESSURE ON INTERLOCKING SYSTEM AT SOUTHERN STATION, BOSTON.

face for reducing it to atmospheric temperature before entering the supply main, and for precipitating the moisture contained in the heated air at a point convenient for its removal periodically.

J. A. COLEMAN.

Liquid Air

The Possibilities of Liquid Air.

By ELIHU THOMSON.*

At the outset it must be understood that in dealing with the present subject the writer does not wish it to be inferred that what he calls possibilities are in his judgment probabilities of the near future, or, that we are upon the eve of any great revolution in engineering methods as the outcome of the recent laboratory studies of liquid air. Much further study and much additional data are required before anything more than mere suggestion can be made in this fascinating field; for, say what we may, the subject possesses an attraction for those who are accustomed to look ahead, remembering that the laboratory experiments of one day and generation have often in the past become the foundations of great industries. It took three-quarters of a century for Davy's electric arc to develop into the

* *Engineering Magazine.*

beginnings of commercial arc lighting, and nearly fifty years elapsed after Faraday's brilliant researches in magneto-electricity before dynamos became a part of engineering. Yet Faraday had built a primitive dynamo and its reversed form was known in primitive types of electric motor.

Who would have supposed, when ammonia gas was first liquefied by pressure, that before the close of the century companies would be doing business by sending it about in pipes for refrigeration? Yet such is the fact.

The splendid studies in liquid air and other gases carried on by Professors Dewar and Fleming, on the very spot where Faraday had made his memorable researches in the liquefaction of gases, form a fitting sequel to the work of that great pioneer.

The object of the present article will be to suggest rather than predict directions in which, under certain conditions, liquid air may possibly become a factor in engineering. And in the absence of favorable conditions need it be said that such possibilities will not be capable of realization?

Let us assume the availibility of some innocuous gas liquefiable at about one hundred atmospheres pressure, at temperatures easily and cheaply attained, and at no cost for the gas itself. In such a case there can be no doubt of its soon finding enormous application in the storage and recovery of energy. Cheap power would be used to compress and liquefy it, after which it would be stored in quantity, either at atmospheric pressure or at some selected higher pressure. Such a liquefied gas would be stable, or remain in the liquid state, if heat were prevented from reaching it. This could be done, not perfectly of course, by surrounding the containing vessel with a liberal thickness of some good non-conductor of heat. That part of the gas which would inevitably escape on account of the lack of perfect heat-insulation would be cold and would be made to traverse the non-conducting covering in successive layers from within outward, and thus assist in cooling the covering and in preventing access of heat to the liquid; or, the escaping gas might even be made available for power in an engine, if the liquid were kept under a proper working pressure. In this case further heating of the gas, analogous to superheating of steam, could be employed before sending it to the engine. But little of the energy of the heat so added would be lost, and a considerable part of it could be supplied by the surrounding air or by water.

With such a liquefied gas produced at one place by cheap power and carried to another for evaporation and recovery of power, ice could be made as a by-product.

In many plants used for the development of power on a large scale, a twenty-four hours' output is not called for, but could be attained at but slight additional expense. The excess power from such a plant needs some means of utilization. This excess power, as during periods of otherwise light load, could be employed to liquefy the assumed gas. On a large scale this procedure would not be costly, supposing the use of highly developed machinery. The liquid product could then be transported in tanks provided with heavy lagging and special arrangements to prevent access of heat from the outside. Perhaps it could be distributed by a well-covered pipe-line. The unavoidable evaporation which would be involved in the pipe-line transportation might not be altogether a loss, for if the line be under a pressure suitable for engines the escaping gas might possibly be tapped out at intervals, heated, and used for power along the line of way.

But the foregoing considerations are based upon the existence of a gas at no cost, with desirable properties rendering its liquefaction easy. Such a gas does not in fact exist. There then arises the question whether we can render available any of the gases known to us. Carbonic-acid gas is cheap, but still far too costly for use in the way proposed. It would not pay to send it back long distances for recompression and reliquefaction. It costs too much to be thrown away after it has been once used.

The air itself meets the condition of no cost for material in the case. We owe much the larger part of our present knowledge of the properties of liquid air to a brilliant series of investigations undertaken some years ago by Professor Dewar at the Royal Institution in London, and continued later by Professors Dewar and Fleming conjointly. The effects of the exceedingly low temperature attained by the evaporation of liquid air, upon electric conductors, dielectrics, electrolytes, etc., have been carefully studied by them. Few

are able to appreciate the labor and pains-taking effort that must have been expended in these researches.

In culmination, Professor Dewar has indeed lately succeeded in reducing even hydrogen to a liquid and in collecting quantities of it. Temperatures not far removed from absolute zero (—273 degrees C.) are obtained by the evaporation of liquid hydrogen. But the absolute zero, like the dynamo of 100 per cent. efficiency, may by each advance be more and more closely approximated but never reached. This low-temperature research has shown that at temperatures as low as —200 degrees C., attainable by evaporation of liquid air, conducting metals, as copper, platinum, silver, etc., when in a very pure state, have their conductivities so much enhanced that electric currents flow with but a fraction of the resistance experienced at ordinary temperatures. Research has shown that at absolute zero they would become perfect conductors. Professors Dewar and Fleming also found that liquid air is a very perfect insulator, and that ice and many frozen electrolytes even become excellent insulators at the temperatures of liquid air; and in general that intense cold in insulators improves the insulation, just as it improves the conductivity of conducting-metals when they are pure.

Unfortunately, however, the liquefaction of air requires rather extreme conditions, and in the early work of Dewar was an exceedingly costly process.

The discovery of the fact that air compressed, cooled and collected in a reservoir at from 100 to 150 atmospheres might be made to liquefy a portion of its own volume, rendered possible the procuring of liquid air by a more direct and simple means. This discovery is claimed by several persons, the merits of whose claims will not be here discussed. When highly compressed air escapes from a suitable orifice it is cooled by its own expansion. If the cooled air be now caused to circulate around a long coiled pipe, which brings the compressed air to the jet in such a way that the portion of pipe nearest the jet is the first to be met by the cooled air, and so back progressively from the jet; further, if the whole be thoroughly jacketed by a non-conducting covering, the temperature at the jet soon falls sufficiently low to cause liquefaction of a portion of the air even at ordinary atmospheric pressure. The operation itself is cumulative or self-intensifying, since the cooling due to expansion is employed, on the regenerator principle, to cool most effectively the compressed gas on its way to the jet and ready to expand.

If air be compressed to about 800 atmospheres it may be made to occupy the same space as it does when liquefied, but even at higher pressures it would remain gaseous. Ordinary temperatures of the surrounding air are far above the critical temperatures of the gases composing it. In order that it may liquefy, it must lose kinetic energy or be cooled; the velocity of the moving molecules must be brought down. The removal of heat is essential, and the process of liquefaction can only be carried on by cooling the gas during or after compression. Conversely, liquid air confined in a closed and filled receptacle, when allowed to regain the heat lost in being liquefied, would become gaseous and exert a pressure of about six tons per square inch.

That the processes for producing liquid air will be developed so as to reduce the cost to an extent such as to render it available in place of a more ideal gas would be a vain prediction to make at present.

Liquid air consists chiefly of a mixture of four parts of nitrogen to one of oxygen. The presence of the oxygen is a disadvantage, inasmuch as fierce combustion, if not explosion, may be occasioned by bringing liquid air into contact with combustibles in presence of a spark or fire. Fine cotton fibre and suchlike substances soaked in liquid oxygen are highly explosive. It is easy, however, to separate the oxygen from the nitrogen by fractional distillation at low temperatures, or methods may be employed to condense the oxygen separately from the nitrogen. Doubtless, oxygen gas so separated from its companion would have a value in chemical and metallurgical processes. The remaining nitrogen liquefied would be perfectly safe. Can it be transported?

The fact that a three-gallon milk-can of liquid air was brought by Mr. Tripler, of New York, from that city to Lynn, Mass., a journey occupying nine hours, and that not more than one-third of the liquefied gas was lost, although the only covering for heat-insulation was about 2½ inches of ordinary steam-pipe felting, goes far toward indicating the possibility

of transportation. With a tank of 20 times the linear dimensions of the milk-can referred to, the surface for loss of heat would rise to 400 times while the capacity would have increased to 8,000 times, and with no better lagging it is easily seen that the daily loss would then be not over 5 per cent. Doubtless, however, improved means for heat-insulation would make the loss but a fraction of this amount. If the tank were kept under a pressure of, say, 200 pounds to the square inch, a suitable safety-valve being provided to prevent excess of pressure, the evaporated gas or air could be made to do work, especially if superheated. If the tank were in a train the motive power might, at least in part, be derived from the normal evaporation from the tanks. Further, let us imagine a pipe-line well insulated for heat, and it is easy to see that if the velocity of flow equalled the train-speed in the journey of the milk-can from New York to Lynn, the percentage loss in a pipe of the diameter of the milk-can with no better lagging than is possessed would be the same or even less. Here again perfection of heat-insulation might make quite a saving, and the evaporated gas might, if the line were under pressure, be made available for power along the line of way.

Whether the liquefied gases of the air can be employed in this way, will, however, depend upon the development of efficient methods of extracting the heat and effecting condensation of the air. That liquid air possesses no advantage for refrigeration is without doubt true, unless the refrigerating effect be obtainable as a by-product, so to speak, of energy conveyance.

Liquid air represents air compressed to about 800 atmospheres, but existing without pressure. No heavy and excessively strong tanks are needed for storing it. If it be pumped into a closed receptacle, under regulated pressure it may be evaporated by the heat of the air, or that of surrounding objects, or it may receive heat from bodies undergoing refrigeration, as water being converted into ice; after which heating operation it may be further heated to the melting-point of lead by heat of combustion, and be finally used in a suitable engine where its expansion may develop power. During its expansion and delivery of power to the pistons of the engine it may become so cooled as to be discharged from the exhaust at nearly normal atmospheric temperature and pressure.

The power expended in compressing and liquefying air is, of course, converted into heat and thrown away. The product, liquid air, has no inherent power of energy in itself. It represents negativity, bearing somewhat the same relation that an exhausted globe does to the surrounding air. It may become the means for rendering the normal energy in the surrounding air available. Liquid air has capacity for taking up the ordinary heat of surrounding objects and thus acquiring pressure. It can be superheated very efficiently, and so used in the form of compressed air in an engine. The superheating will, of course, tend to raise greatly the total efficiency. The inevitable losses in the compressing and liquefying processes would in part be made up in the added heat, the amount of which is small and efficiently employed. We have no reliable data of large-scale operations, and can as yet reach no certainty as to the efficiency attainable in compression and liquefaction or in recovery of power. It is possible that the separation of oxygen which would probably possess a value in metallurgy, might tend to diminish the cost of condensation. So also the refrigeration which is obtained during evaporation might help the recovery end. Where so much is "in the air" we must be content with suggestions only, and they may never be realized in practice. The power required to be expended in liquefying a given amount of air can be approximately estimated, and an assumed efficiency of plant may be made to do duty in place of exact figures where none are to be had, and if the conclusions based thereon are understood as tentative and subject to extensive modification in view of further advances in our knowledge, no harm is done.

In making an estimate of the cost of liquid air as produced on the large scale, the factors of plant-efficiency, maintenance, etc., come in to a greater or less extent. Assuming that air be compressed as nearly isothermally as possible, and that in a large plant a possible total efficiency of seventy per cent. might probably be realized, each horse-power hour might thus be expected to compress nearly 10 pounds of air to a pressure of 2,000 pounds to the square inch. If such com-

pressed air, on being expanded in a very carefully arranged self-intensifying apparatus should condense 25 per cent. of the air admitted we would have about 2½ pounds of liquid air per horse-power hour. The assumed proportion, 25 per cent., seems not improbable in view of all the data—meagre enough, it is true—which have come to the writer's knowledge.

If the power cost be taken at $20 per year in large units and an additional charge of $10 be allowed for each horse-power of the compressing and condensing plant, its interest, maintenance, and operating expenses, the cost per pound of liquid air would be about one-sixth of a cent, assuming the plant to run 7,200 hours per year. This estimate, subject to modification from the very nature of the problem, would make the liquid air cost for production about 8 cents per cubic foot. If oxygen, separated by fractional distillation, possessed a value for equal amounts in excess of the cost of the air the remaining nitrogen would, of course, be producible at a lower figure.

It is probably within the possibilities that a cubic foot of liquid air or nitrogen, if allowed to heat from its surroundings and then be further heated to 200 degrees C., could, in a high-pressure engine, yield about five horse-power hours. If at the same time the vaporization of the air were attended by useful refrigeration, as in making ice, the cost of recovery would diminish. Need it be said here, however, that even if the cost of horse-power of recovered energy much exceeded that which is indicated in the foregoing estimates or assumptions, a demand may still exist for a source of power having great compactness, freedom from nuisance, no heated nor noxious exhaust, and of unequaled controllability? The horseless-vehicle problem certainly presents us with an instance in point.

It would seem, however, that certain uses may be found for liquid air in which considerations of cost are not so important as is the ability to obtain the effects in view. In warfare, for example, the possession of highly concentrated energy-stores under control is very important. Liquid air can be rapidly converted into compressed air at six tons per square inch. This would probably be useful in the projection of high explosives. Compressed air is now used for propelling mobile torpedoes, or fish-torpedoes as they are called. Dirigible torpedoes either depend for power upon compressed air or the electric energy of a storage battery. Compressed air requires high pressures and very strong and heavy containing-vessels. Liquid air can be stored without pressure or at low pressures, and can be evaporated at any desired pressure, while its bulk represents that of air under 800 atmospheres. A storage battery would probably be from five to ten times as heavy as liquid air in a receptacle, for equal available energy. But no storage-battery could be discharged at an equivalent rate.

Submarine boats and flying machines may yet find use for liquid air. In the submarine boat it could be evaporated by the heat of the surrounding water, and after furnishing power it would ventilate the boat. Before its final discharge it could be burnt with oil in a fuel-engine for further power. We may find use for it in the flying machine. For emergency work it could in evaporating cool the cylinders of a fuel engine and yield power as a result. Moreover, control of the submergence of a boat could be effected by the use of liquid air, so easily gasified, to add to the displacement.

The great feature of the application of such a power as liquid air would be its emergency value. By this is meant the ability to obtain at will a sudden output far beyond the normal. Animal power notably possesses this emergency value, and the success of electric trolley systems largely depends upon the fact that, when needed, the station can be called upon for a temporary delivery to any single car or train, of a power greatly in excess of the rated output of the motors.

Suggestions have already been made of the use of liquid air or oxygen, mixed with combustibles as a high explosive. Such an explosive can be made at the time of use, and if left unexploded, either by accident or design, soon loses its dangerous character by evaporation of the liquid gas.

Liquid air may also be used in the rapid production of high vacua. Let the bulb to be exhausted be filled with a gas such as corbonic acid, more condensible than air, and be provided with an extension that can at any time be sealed off. If now the extension-piece be immersed in liquid air the condensible gas will be taken from the bulb and deposited in the solid state in the extension-piece. This is

now sealed off, leaving a high vacuum in the bulb, particularly if the same be heated during the process.

A fascinating speculation for the electrical engineer is the possibility of so cooling the conductors of electric lines or apparatus as to improve the conductivity many times, and so diminish the losses in any given length of conductor, and at the same time greatly improve the insulation. Professors Dewar and Fleming have shown, however, that it is a condition of this enormous improvement in conductivity that the metals be very pure, a very small percentage of impurity greatly lessening the result. As regards the insulation, they have shown that dielectrics and even electrolytes become insulators of excellent character when cooled to the temperature of liquid air. What effect such a lowering of temperature would have upon the dielectric strength or striking distance between conductors at great differences of potential is not as yet determined, so far as the writer is aware. The result to be expected from a consideration of the effect of heating upon dielectric strength or striking distance is that very low temperature will make it far more difficult to break down insulation by sparking through it.

That the electrical engineer covets just such agencies as will thus extend the range of possibilities in his art needs no proof. He would be apt to choose a pipe-line conveying liquid air as the very best location for his conductors, assumed to be made of as pure metal as possible, the high insulation probably attainable being the chief object. Whether his conductors were placed outside such a pipe or within the same, he could no doubt adapt himself to the conditions, provided he could get the benefit of the low temperature insulation, and possibly, to a certain extent, a gain in conduction.

It is indeed very questionable whether a pipe-line will ever be laid and kept filled with liquid air solely for its electrical benefits, but if such a line were also used to supply liquid air to a distant point and the normal evaporation utilized, the case would be somewhat modified, though the improbability of such a combination being put into service, at least within any reasonable period, still remains.

It will be the proper attitude for the conservative and at the same time progressive engineer to await the possession of full and accurate data before drawing any conclusions as to future practice. Suggestions of possibilities are, of course, useful, even if only a fraction of them prove realizable, and no attempt is here made to do otherwise than call attention to matters which must from their nature possess more or less of interest.

Liquid Air and Low Temperatures.

W. H. SWENARTON.*

Probably no other discovery of the last quarter of a century has created such widespread interest and astonishment as the simultaneous liquefaction, by Messrs. Pictet and Cailletet in 1877, of air, hitherto considered as a permanent or incondensable gas. This discovery was of little value commercially, however, because of the enormous expense of the product, and therefore, outside of its value as a scientific achievement, it was practically worthless. With the recent anaouncement, however, by Mr. Tripler of New York, that he can produce this substance in practically unlimited quantities, the value of this product assumes more tangible proportions, as the uses to which this inconceivably cold and extremely volatile liquid can be put are almost innumerable.

The evolution of the production of low temperatures has been gradual yet wonderful in its development. Two hundred years ago when Fahrenheit was striving to produce cold by artificial means for the sake of establishing a zero for his new thermometric scale he boasted that no one could obtain a lower temperature than that which he had produced by a mixture of snow and ice. Since Fahrenheit's day scientists have been gradually probing the depths of temperature, until to-day a point over 400 degrees below the lowest point ever reached by Fahrenheit, has been obtained.

Three methods for producing low temperatures are known. 1st: By the rapid solution of a solid. 2d: By the rapid evaporation of a volatile liquid. 3d: By the rapid expansion of a cooled and compressed gas.

Up to 1820 the first method, that is, a freezing mixture, was used entirely, and in this manner a temperature of 50 degrees below zero centigrade was obtained.

* *Yale Scientific Monthly.*

In 1823, Faraday, by combining pressure with refrigeration, succeeded in liquefying all except six of the existing gases, namely, by heating in one limb of a sealed siphon a mixture which evolved the desired gas, and immersing the other limb in a freezing mixture. The gas was thus liquefied in the cold limb by pressure proceeding from its own expansion. Faraday reached a limit, however, in oxygen, hydrogen, nitrogen, nitric oxide, carbon monoxide, and marsh gas. He subjected them to a pressure of 1,000 pounds per square inch, subsequently increased by others to 4,000 pounds, without affecting their liquefaction. Hence these gases were termed permanent, or incondensable gases, because it was supposed that they would remain gaseous under any conditions.

It was not until 1869 when Dr. Andrews of Belfast discovered the important fact that unless these gases be cooled to a certain temperature, known as the critical temperature, and varying in different gases as the following table will show, no amount of pressure will liquefy them.

CRITICAL CONSTANTS.

	Temperature in Degrees Centigrade.	*Pressure in Atmospheres.
Hydrogen,	—240	13.3
Nitrogen,	—146	33.
Carbon monoxide,	—140	39.
Oxygen	—119	50.
Methane,	—100	50.
Nitric oxide	— 93	71.
Tthylene,	+ 10	51.
Carbon dioxide,	+ 32	77.
Nitrous oxide,	+ 53	75.
Acetylene,	+ 57	68.

This important discovery created quite a sensation in the "scientific world" and gave a new impulse to the workers in this field of physical research. Chief among these were Pictet, a Swiss chemist, and a French chemist, Cailletet. These two men although working and investigating entirely independent and ignorant of each other, simultaneously announced to the Academy of Sciences on December 24th, 1877, their success in liquefying air. The incredulousness of this discovery to the public may be compared to that of a skeptical African chief, who, having accepted the many reports as related to him by his white visitor, absolutely refused to believe him, when he was told that, owing to the intense cold in some countries, the rivers became so solid that people actually walked over them.

Pictet cooled carbon dioxide by surrounding it with liquid sulphurous acid until a temperature was reached at which it liquefied. (Although at atmospheric pressure the boiling point of sulphurous acid is relatively high at reduced pressure it is very much lower). He then obtained a still greater degree of cold, by allowing the liquid carbon dioxide to evaporate rapidly in an exhausted space. The oxygen was generated in the usual way from potassium chlorate, by heating it in a strong iron retort. In this way a pressure of several hundred atmospheres was obtained. The retort was then surrounded by this liquid carbon dioxide, boiling in a vacuum, and a temperature finally resulted, which liquefied the oxygen.

Cailletet's process was practically the same as the one in use at present. His method consisted in exposing the oxygen, or whatever gas he wished to liquefy to enormous pressure produced by means of a hydraulic press, while at the same time the temperature was lowered, by suddenly allowing the gas to expand. In this manner a sudden disappearance of heat energy occurred, it being absorbed and transformed into mechanical motion. By this method Cailletet succeeded in liquefying hydrogen, a gas whose critical temperature is but 33 degrees centigrade, above the absolute zero of temperature, that is, the point where a gas, if it did not liquefy would have zero volume, but as matter is indestructible, it is evident that every gas must liquefy before the absolute zero of temperature is reached. He was unable to collect any of the liquid hydrogen, however, it merely appearing as a mist on the inside of his tube, when the great pressure of 300 atmospheres, to which the gas was subjected, was suddenly relieved. The explanation of this method is that the gas first of all cooled, on account of its quick expansion, because of the transformation of the heat energy into mechanical motion, in temperature below its critical point and then becomes liquefied under the enormous pressure to which it is subjected.

These results by Cailletet and Pictet, and a few years later Dewar, led to the inevitable conclusion that solids, liquids, and gases were but different forms of

* The above equals the amount of pressure required to liquefy a gas when cooled to the critical temperature and is known as the critical pressure.

matter through which any substance could be made to pass by the addition or withdrawal of heat and pressure. It was held that every known substance, that is any of the elements, would behave similarly if heated or cooled sufficiently.

Professor Dewar of Glasgow, working in the same laboratory in which Faraday so successfully experimented, succeeded in 1883 in liquefying all known gases except hydrogen and fluorine. His method involved practically the same process as that employed by Pictet in 1877, except that he cooled and liquefied ethylene gas, instead of carbon dioxide gas, with sulphur dioxide. Then by means of the liquid ethylene, boiling in a vacuum, he cooled air and other gases below their critical temperatures and liquefied them by pressure, due to their own expansion. To him belongs the credit of first liquefying air in quantity.

Liquefied air and nitrogen were first collected in any desirable quantity by Olzewski, in 1885. Later, by using oxygen as a cooling agent, he cooled a tube containing hydrogen under a compression of 150 atmospheres, to 211 degrees below zero centigrade, and then by further cooling the hydrogen, by allowing the confined gas to suddenly expand to a pressure of only 20 atmospheres, he obtained liquid hydrogen. By boiling liquid oxygen in a vacuum he obtained a temperature of 225 degrees below zero centigrade. By boiling the liquid hydrogen, which he subsequently obtained, in a vacuum, a temperature of —264 degrees C. was obtained, but 9 degrees from that coveted absolute zero of temperature, which scientists have sought for as eagerly as have explorers the North Pole. Olezwski's process was, however, very complex and expensive.

The economical liquefaction of air has only very recently been accomplished by Mr. Tripler of New York, who has for many years been experimenting and striving to reach this end. His method is what is known as the "self intensifaction of cold," or the method of the expansion of air under pressure. In short, he produces liquid air simply by the expansion of compressed and cooled air, without employing any other substance than liquefied air to bring this about. Mr. Tripler first produced liquid air in 1890 by the same method used by him to-day, only of course with very crude apparatus. His apparatus consisted of a compressor connected by a tube to a coil, containing an inner tube which has a valve at the top. This coil is in turn surrounded by a glass tube 12 in. by 1 3-16 in. diameter open at the bottom. Air under a compression of 2,000 pounds is forced from the compressor through the coil, up through an inner tube, and out a valve at the top. By the expansion of the escaping air, the coil and the inner tube were so cooled, that liquid air trickled down the pipes and dropped out at the bottom of the tube. The plant as it is to-day, after eight years of experimenting and testing, consists of a triple air compressor, a cooler and a liquefier. The compressor is of the ordinary form having three pumps upon one piston shaft, working in a line. The first pump compresses the air to 60 pounds per square inch; the second raises this to 750, while the third brings the air under a compression of 2,000 pounds per square inch. After each compression the air is forced through jacketed pipes, in which it is cooled by city water to about 50 degrees Fahrenheit. After the third compression (40 H. P. is used for this compression) it flows through a purifier and thence into what is termed a liquefier. This appatarus consists of a felt and canvas-covered tube, 15 feet long and 1½ feet in diameter, placed about five feet above the floor. The interior is full of pipes and coils. These are in two sets, the first of which contains compressed air to be liquefied while the second is filled with compressed air which is to do the liquefying. By means of a valve this air is allowed to escape through a small hole when it rapidly expands and rushes over the first set of pipes greedily licking up all the heat contained in them. Finally after about five minutes, so much heat has been extracted from the first set of pipes that the air in them is cooled way below the critical temperature, and owing to the intense cold and the enormous pressure, this air becomes liquefied. Oftentimes such a cold prevails in the apparatus at this stage, that even the air used to do the liquefying is liquefied and sometimes even frozen. If now the valve in the first set of pipes be turned, liquid air rushes out in the form of a dense white chilly mist as on exposure to the normal air, which is 390 degrees F. hotter than the liquid air, it instantly vaporizes.

Thus Mr. Tripler makes liquid air at a cost of about 20 cents a gallon. It is this fact wherein the value of Mr. Tripler's method lies. The production of liquid air

by Dewar in 1885 at a cost of $500 a pint, was hailed by scientists as a very creditable achievement. From this fact a slight idea of the greatness of Mr. Tripler's accomplishment may be seen.

With some of this liquid air produced by Mr. Tripler, Professor Barker, of the University of Pennsylvania, recently performed before the students a very interesting series of experiments. By means of this extremely cold liquid, he froze mercury and alcohol, the thermometric substances. When iron, tin, steel or rubber were dipped in this liquid they became extremely brittle. The tensile strength of metals was found to be vastly greater after immersion in this liquefied air, and in the case of iron this increase reached 88 per cent. In the same manner the electric resistance decreased after immersion, and it is claimed after numerous experiments and profuse calculations, that all metals would become perfect conductors at absolute zero. It is by their practical application of this phenomenon that these extremely low temperatures are measured; namely, by measuring the resistance of a platinum wire before, and after, immersion in the liquid whose temperature is to be measured. Then from these resistances the temperature of the liquid can be calculated.

Perhaps the most startling experiment performed by Professor Barker was the placing of an ordinary tea kettle containing liquid over an intensely hot flame. This caused the liquid to boil terrifically and it shot from the spout in straight columns three or four feet into the air. The carbon dioxide generated by the flame froze in a solid layer on the bottom of the kettle which was but a few inches from the flame. When a glass of water was poured into this seething liquid it was frozen solid, although the liquid was at a temperature of 191 degrees below zero centigrade, when the hand was dipped into it a sensation indistinguishable from that of a severe scald was experienced. If, however, the hand were withdrawn immediately, no injury resulted, because the moisture on the hand evaporating, formed a sort of non-conducting cushion. When, however, the hand was not immediately withdrawn it was soon robbed of its protecting cushion, and severely scarred. When this liquid air was poured from the kettle and filtered, to free it from the frozen particles floating in it, the liquid was seen to be of a pale blue color. This liquid was almost pure liquid oxygen as in the previous boiling most of the nitrogen—the other constituent of liquid air—was distilled off, for its boiling point is 13 degrees C. below that of oxygen. From the pale blue color of this diluted oxygen, as it still contains liquid nitrogen, which is colorless, and from the indigo blue color of ozone, that is, condensed oxygen, a theory has been advanced, attributing the blueness of the sky to the oxygen in the air. When phosphorus, for which oxygen at ordinary temperature has a great affinity, is brought in contact with liquid oxygen, no combination and vigorous combustion results, as takes place at ordinary temperature. Should the liquid air be confined in a vessel a terrific explosion would result, as one volume of this liquid air will expand to 748 volumes of gaseous air. If placed in an ordinary open glass flask, or bulb, the liquid air will rapidly volatilize and the moisture in the surrounding air will be condensed and frozen in the form of a shaggy white coating on the outside of the flask. A very suitable receptacle for this liquid was devised by Professor Dewar. This is merely a double globe with a vacuum between, which being a non-conductor of heat prevents the passage of it by convection. Heat is conveyed in another manner, however, namely, by radiation. To prevent this the inside of the outer globe was silvered. It was found that liquid air would last 10 times as long in a silvered Dewar bulb as in an unsilvered one. Another very excellent apparatus for storing liquid air consists of four globes, one within the other. In the first or outer space, between the first two globes, is inserted a mixture of liquid carbon dioxide and ether, which is at a temperature of -110 degrees C. In the second space liquid ethylene is placed, at -160 degrees C. In the third space liquid oxygen or air at -190 degrees, and in the fourth space the liquid air to be stored, also at a temperature of —190 degrees. With this receptacle, although there is considerable loss by evaporation, it is possible to store the liquid air for a reasonable length of time. The uses to which this condensed gas can be put are innumerable. Probably its greatest future use will be as a source of power. It will be extremely valuable for medicinal purposes and surgery. For refrigerating purposes it will be almost indispensable. As an explosive it will rival, and even surpass, nitro-glycerine and dynamite.

Mining and Kindred Enterprises

Pneumatic Cyanide Process.

Under various forms the mining papers of the West have been printing the account of what is called the Pneumatic Cyanide Process. It is claimed that it will revolutionize the treatment of ore.

The features of the "Pneumatic" process are so easily understood that it does not require an "expert" or a thorough chemist to appreciate them, for every mining man has had more or less experience with compressed air, and most of them know something about the cyanide process and understand that oxygen is absolutely necessary in a solution of cyanide of potassium in order to form a new compound called "Cyanogen," which is the true solvent of the gold. They know also that agitation hastens the process of dissolving and extracting the values during the leaching process, because agitation, or stirring, enables the oxygen of the air to reach the solution more rapidly to form "Cyanogen" and also to bring the ore and solution into more intimate contact, and does in a few hours what it takes days to do if the ore and solution remain unmoved in the leaching vats.

Many attempts have been made to stir or agitate the mass of leaching ore by machinery; but the great cost of power, expensive construction, breakage of parts, etc., have caused them to be abandoned, and mill owners have gone back to the old slow process of letting the ore stand for days in the leaching vats because there was no practical and cheap way of agitating them, or of getting the oxygen through the solution, except by the slow absorption from the atmosphere.

Just at this time, when it seemed as if improvement in the cyanide process was at a standstill, the "Pneumatic" process comes forward with a method so simple and so effective that, as we said before, it is a wonder that it was not thought of sooner.

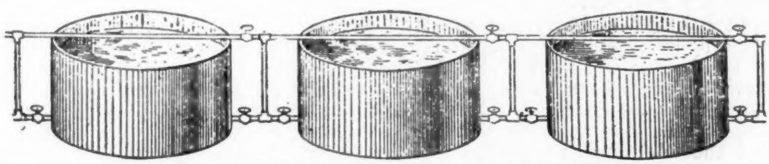


FIG. NO. 1 SHOWS A SERIES OF LEACHING VATS, OR TANKS, FITTED WITH PIPES AND VALVES FOR THE INTRODUCTION AND CONTROL OF THE COMPRESSED AIR.

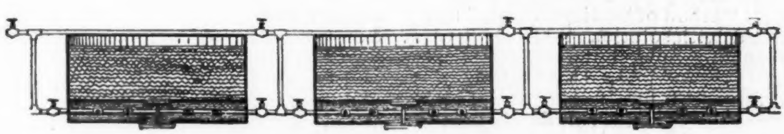


FIG. NO. 2 IS A CROSS SECTION, CUT THROUGH THE MIDDLE OF NO. 1, AND SHOWS THE AIR PIPES BETWEEN THE TRUE AND THE PERFORATED FALSE BOTTOMS OF THE VATS, AND THE TRAP DOOR IN THE BOTTOM FOR DISCHARGING THE LEACHED REFUSE.

It is simply the introduction of strong currents of compressed air into the bottom of the leaching vats, which force their way upward bubbling and boiling through the mass of crushed ores and cyanide solution, and thus furnish both the oxygen and the agitation needed for the rapid and thorough extraction of the gold. This method of forcing the air through the leaching ores can be readily understood by means of the cuts shown.

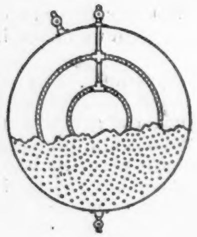


FIG. No. 3.

No. 3 is a view of the bottom of a leaching vat, with a portion of the perforated false bottom cut away to show the coil of perforated air pipe, by which the compressed air is evenly distributed over the entire bottom of the vat.

It can be readily seen from these illustrations how fully this process solves the problem of leaching the ores rapidly and thoroughly—requiring only hours where old methods required days. It also drives all the slimes to the surface, where they cannot interfere with percolation, as they do when permitted to settle at the bottom of the vats.

Experience has proven that a hot solution of cyanide of potassium is more effective in dissolving gold than a cold one; but until this process was invented, no practical method of heating rows of large vats filled with solution and leaching ores was known. Now, however, by simply passing the compressed air through a small furnace before forcing it into the bottom of the vats, the solution is heated, the extraction hastened and increased, and all danger of freezing in cold weather obviated; an improvement which mill owners in high altitudes will certainly appreciate.

The method of precipitating the gold from the cyanide solution after the leaching process is completed is also an improvement over the present methods, and is covered and protected by a separate patent. It has all the good qualities of the old zinc box, with the addition of three new features which aid in rapid precipitation and leave the solution in better condition for using a second time

The inventor of the process has been working quietly for nearly three years in perfecting it and securing his foreign patents, and it has been before the public for only a few weeks. The system is now being installed by the Pneumatic Cyanide Process Co. of Denver, Col.

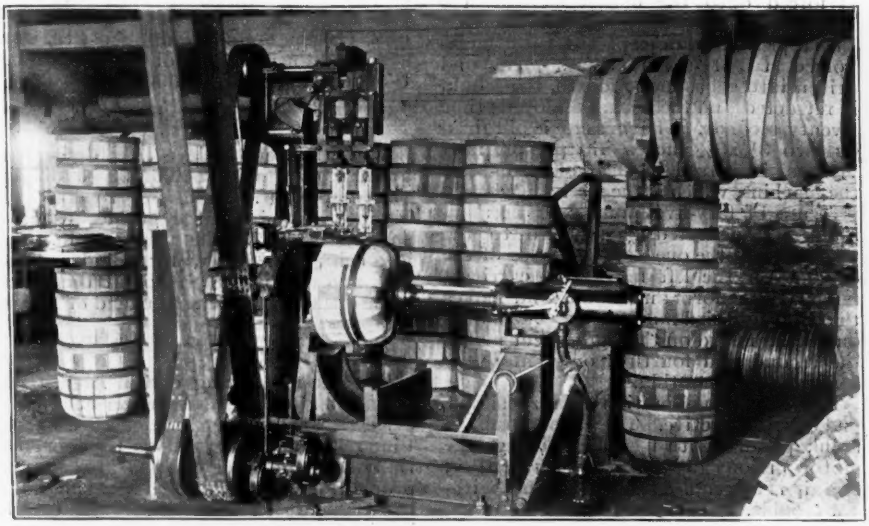
The Use of Compressed Air in Mines.

Of late years compressed air has gained greatly in prominence as a means for the transmission of power, and now occupies a broad field of usefulness. In addition to its value and convenience as a power transmitter for engineering purposes it possesses also characteristics which make it applicable to a great variety of uses in the manufacturing industries and mechanic arts, in which the element of actual transmission of power does not at all enter. A discussion of these, however, would not be appropriate here.

In connection with mining, tunneling, shaft sinking, and kindred operations, compressed air has found several of its most important applications. Here, for some purposes, it has made a place for itself in competition with steam, but it is in conjunction with steam and other prime movers that compressed air, acting purely as an agency for transmitting power, has frequently become indispensable for underground work. As compared with steam the employment of compressed air for such purposes is particularly valuable and convenient for four reasons: First, its transmission loss is small; second, the troublesome question of the disposal of exhaust steam underground is avoided; third, the exhaust air is of direct assistance in the ventilation of the confined working places, and fourth, its capacity for storing power makes it well adapted for intermittent work. These points will be briefly considered.

The conveyance of steam long distances underground involves serious and unavoidable loss from radiation and consequent condensation. The loss due to friction is common to both steam and compressed air, and although not equal at the same pressure, on account of the greater density of compressed air, the one may be taken as approximately offsetting the other. In a steam pipe of proper diameter, under given conditions, the frictional loss should be not more than one-fifth the loss from radiation. Condensation may be reduced by carefully covering the piping with good non-conducting material, but even with the best covering the effective pressure at a distant underground engine is greatly diminished, and very uneconomical working is the result. In conveying steam a distance of several thousand feet, as is by no means uncommon

in extensive collieries, the pressure may be reduced to half the boiler pressure, or even less. Take, for example, a pump situated 2,000 feet from the boiler and using 200 cubic feet of steam per minute at a boiler pressure of 75 pounds, with a mineral-wool covered pipe, 4 inches in diameter, the effective pressure at the pump would be only about 58 pounds, or, with a poor covering, like some of the asbestos lagging often used, it might easily be as low as 35 pounds. For compressed-air transmission the reduction of pressure for the same volume of air, size of pipe, and initial pressure, would be 9.3 pounds, giving a terminal pressure of 65.7 pounds. But, as the speed of flow in pipes for economical transmission is greater for steam than for air, a comparison based on piping of the same diameter cannot justly be made. If, in the above example, the diameter of pipe were smaller the gain in reduced radiation would outweigh the increased frictional loss, and the net loss would be diminished. The frictional loss varies inversely, and the loss from radiation directly, with the diameter. Therefore, under given conditions, the diameter of the pipe can be so proportioned as to produce a minimum loss. With compressed air transmission, however, the case is different. For, if the diameter of the pipe in the above case be increased to 5 inches, the loss of pressure, or head required to overcome friction, is reduced to 2.8 pounds, and increasing the distance to one mile it would be only 7.4 pounds. Furthermore, the increased cost of the larger air-pipe would be offset by the expense of the non-conducting covering. No account has been taken here of the loss due to leakage. Attention may be called to the fact that little or no danger is to be apprehended from the rupture of a compressed air pipe, while the bursting of a steam pipe in a shaft or in the mine workings may be a serious matter.—Western Mining World.



Basket Making by Compressed Air.

Compressed Air Machinery

It makes Baskets.

The apparatus illustrated herewith is a basket-making machine, operated by compressed air. It is one of the latest applications of air power.

This machine is now making 180 bushel baskets per hour at the Michigan Basket Factory of Wells, Highman & Co., at Traverse City, Mich. It was designed and built by Wm. Jackson, machinist, of the above place, and was patented in February last.

The staves of the baskets are fastened to the hoops by staples of wire taken from the coil, formed and driven by the machine. The basket staves (before moulding) radiate from a center to a disc-like form, and to bend them to the shape of the basket form four movements of the machine are made. These movements are obtained by the use of compressed air. First, to move the basket form from beneath the stapling devices; second, a disc is forced onto the basket form by the mould; third, the form is carried under the staplers, the hoops placed, the form revolved, twenty-seven staples made and driven into each hoop; fourth the mould is retracted and the basket removed; time twenty seconds. The pressure is obtained by two 3½x3½ inches air pumps, inlet pistons, immersed in the hollow base of the machine, which is the receiver, where a pressure of fifty-five pounds is accumulated and delivered as required to the two motors; the one near the base of the column on the left moves the carriage, mounting the form and mould, and makes the first and third movements. The motor on the standard on the right of cut makes the second and fourth movements very swiftly and smoothly.

The whole combination is very simple and equally effective. The air pumps have trunk pistons with metallic packing; the motor pistons are packed with leather; the air is not cooled; runs ten hours without trouble, has one hour's rest at noon.

Air Jets

In the March number of "Compressed Air" we called attention to the safety of pneumatic traction being assured by the use of weldless cold-drawn steel tubes in which the air is stored. These tubes have been made in Germany. It is announced by the Shelby Steel Tube Co., Cleveland, Ohio, that they are prepared to make seamless compressed air bottles which will accommodate high pressures such as are used in street railway cars. This company contemplates entering the field with a full line of cylinders for compressed air applications. The bottles made by them are of various diameters and lengths.

The Chicago Pneumatic Tool Co. has purchased the patents formerly owned by the Consolidated Pneumatic Tool Co., now defunct. These patents include all the Keller and Wolstencroft types of tool construction and in addition several new applications which have not yet been taken out. These patents originally cost the Consolidated Pneumatic Tool Co. about forty thousand dollars ($40,000).

M. L. Minzey, Bellevue, O., desires the address of parties making a hydraulic air compressor. He desires to compress air into a receiver at a greater pressure than there is on the water main. The idea being to have a water cylinder at one end, and an air compressor at the other, to be operated by water instead of steam.

At a recent meeting of the French Association for the Advancement of the Sciences, M. Dommer announced that Dr. Linde was now engaged on the construction of a small piece of apparatus for the production of liquid air, which will weigh less than 2½ lbs., and will liquefy the air in eighteen minutes.

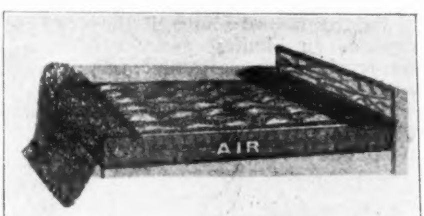
At a recent meeting of the Eastern Association of Physics Teachers, at Springfield, Mass., some very interesting experiments were made with liquid air. The exhibition was conducted by C. F. Warner, Principle of the Mechanics' Arts High School, of Springfield. He said that the idea of producing liquefaction by cold was discovered in 1869, by Dr. Andrews, of Belfast. The experiments consisted of a series of demonstrations similar to those already described in these pages.

Mr. Fugita, Ch. Engineer, of Japan, recently visited New York, and among other matters looked into compressed air as a motive power for street railway purposes. Owing to the extremely narrow streets in all of the Japanese cities, compressed air is looked upon as an ideal motive power.

The Fountain Air Brush is described as having done away with all the unpleasant and complicated features of the early air brush. The Fountain Air Brush is shaped like and is but a little larger than a lead pencil, and is held in the hand the same as a pen or pencil. It applies color in large quantities in a very short time and is yet adjustable for the finest line.

The description of any plant using compressed air is always interesting to the readers of this little magazine, and the engineer or mechanic in charge of such a plant will confer a favor by advising what is being done, the means of doing it, and the general and detailed information regarding it. An account of any new invention or application of compressed air will be published, giving due credit to the author and inventor.

Pneumatic beds, pillows and cushions have been used for many years in hospitals and sick rooms to ease the sufferer's



pain, but it is only lately that they have been manufactured for domestic use. The Air-bed Pillow and Cushion Co., with factory at Moberly, Mo., are now turning out several hundred monthly, and report that their customers are well pleased with them. In appearance they are much the same as other mattrasses. The hospital beds are quite expensive, but these made for general use are within the reach of most people.

Pneumatic Horse Collar certainly has not caught the popular fancy, and the promoters feel much aggrieved in consequence. Wall street speculators evidently object to a halter around their neck. Anyway, in these days of electricity we have very little use for horses or their trappings, except for blooded stock.—Town Topics.

Jenckes—They say that liquid air is the coldest thing known. I wonder if it will ever be put to any use.

Jenkins—Of course it will. Properly flavored it will be sold in Boston for ice cream.—Town Topics.

The Pneumatic Supply & Equipment Co. has been organized under the laws of the State of New York and has opened an office at 120 Liberty Street, New York. It is the purpose of this company, as its name implies, to deal generally in compressed air equipment, and it will make a specialty of the installation of complete plants, eliminating the division of responsibility which has heretofore existed in the trade. The Company is bringing out several specialties in the compressed air line, such as pneumatic oil rivet forges, quick-acting hose couplings, and has in addition closed agencies for several standard types of compressors.

Mr. J. W. Duntley, the president of the Chicago Pneumatic Tool Co., is the president of the new company. Mr. E. B. Gallaher, formerly with Messrs. Patterson, Gottfried & Hunter, is the vice-president and engineer, and Mr. W. P. Pressinger, formerly manager of the Clayton Air Compressor Works, is secretary and treasurer.

We are in receipt of Cat. No. 10 of air compressors built by the Clayton Air Compressor Works, New York. It describes and illustrates air compressors.

Walter H. Foster, 126 Liberty Street, New York, is the New York agent for the U. Baird Machine Company's Portable, Motor and Belt Driven, Air Compressors. These compressors are applicable to all purposes, where a small amount of air is required, and where the portable feat-

ures are considered. The compressor and receiver are mounted on a truck similar to an ordinary warehouse truck, and they can be conveniently moved from one point to another.

If you have back numbers of "Compressed Air" for which you have no need, we will be glad to have them. We will pay liberal prices for scarce copies. Among those we are short are July 1896, November 1896, March 1897, Feb. 1898. Twenty-five cents each for any of the above.

The Tubular Dispatch Co., owning and operating the Pneumatic Mail Transmission Tubes in New York City, has placed an order for three Duplex Corliss Air Compressors, with the Pneumatic Supply & Equipment Co. of New York, recently organized to install complete compressed air plants. These three compressors are to be located in the sub-basement of the Metropolitan Life Insurance Building, New York City. The capacity of each compressor is in excess of thirteen hundred cubic feet of free air per minute, and the entire cost of the installation is understood to be over twelve thousand dollars ($12,000).

By an arrangement recently made, the Chicago Pneumatic Tool Company have arranged with the National Pneumatic Tool Company to sell the entire output of their factory, in connection with the large line of pneumatic tools now handled by the Chicago Company. This gives the Chicago Pneumatic Tool Company control of the sales of the Phoenix Rotary Drills, the new Heaseler piston drills and the appliances manufactured by the National Pneumatic Tool Company, as well as the Boyer Riveters, Hammers and Piston Air Drills.

Orders to the National Company will receive prompt attention as heretofore, and the Chicago Company are prepared to supply any tools wanted in either line.

The arrangement is amicable on both sides, and is for the purpose of reducing selling expenses on both lines of tools.

COMMUNICATIONS.

Under this heading will be published inquiries addressed to the Editor of COMPRESSED AIR. We wish to encourage our readers in the practice of making inquiries and expressing opinions.

We request that the rules governing such correspondence will be observed, viz: all communications should be written on one side of the paper only; they should be short and to the point.

"Compressed Air":

The Library Committee of the Western Society of Engineers is trying to complete several publications for binding. We find we have "Compressed Air" up to date, but lack indexes for Vols. 1 and 2. Can you supply us?

Frank P. Kellogg.

Ann Arbor, Mich., May 9, 1899.

"Compressed Air":

We have a complete set of "Compressed Air," kindly furnished by you, except Nos. 1, 2 and 10 of Vol. 1, and the indexes to Vols. 1 and 2. Some time ago you informed us that No. 1 of Vol. 1 was out of print. Sometimes copies of out of print matter turn up unexpectedly. If this has been the case with this number, we shall be most glad to get a copy of it. I also solicit Nos. 2 and 10 and the indexes named above, if they can be supplied. In binding your volumes, do you retain advertisements? Shall you continue to page continuously?

A. C. DAVIS, *Librarian.*

ANN ARBOR UNIVERSITY.

"Compressed Air":

I think it would be valued by your readers if you could give a diagram showing the temperature and volume which would result from compressing air, adiabatically, and in a single stage, to very high pressures, say 2,500 to 3,000 lbs. per square inch. Probably only an approximation could be given, but even that would be serviceable. Failing this, could you give a constant to enable same to be determined by calculation?

Is there a point in air compression where the temperature reaches a maxi-

mum above which continued compression cannot increase the sensible heat? Suppose this were so and that we had compressed a quantity of air far beyond its (heat) saturation point. Assuming that we use this immediately in a motor, how will cooling take place? Must the pressure fall to the heat saturation point again before the temperature begins to fall, or does temperature fall at once?

If there is a heat saturation point, must there not also be a cold saturation point? Suppose that in using the above quantity of highly compressed air, we had first allowed it to fall to atmospheric temperature, would it continue to fall in temperature so long as expansion took place?

In the compression of air temperature rises most during the early stages. How is it in expansion? Is it vice versa?

T. T.

Newcastle-on-Tyne, Eng.

A diagram of adiabatic air compression, to be of any value, should be made on a larger scale than our space will allow, if carried up to 3,000 lbs. per square in. pressure. Compression to the higher figures is not practicable by one stage compression, for at 1,000 lbs. pressure the air rises to a full red heat, 1313 degrees Fah., and at 2,000 lbs. to 1709 degrees Fah.

This is the theoretical temperature, but as much of the heat in the air would be absorbed by the compressor, it would soon become too hot for economical operation.

The formula for the temperature of compression is derived from the relative absolute pressures and a ratio of adiabatic compression for gases. $\left(\frac{p}{P}\right)^{0.29} \times (461.2+t^\circ) = T^\circ$ Fah., in which p=the ultimate absolute pressure, *i.e.*, the gauge pressure plus 14.7 and P=the atmospheric pressure, 14.7. t=the initial temperature from zero Fahrenheit. —461.2 is the temperature from absolute zero to the zero of the Fahrenheit scale.

The ratio exponent, 0.29, is derived from the quotient of the division of the specific heat of air at constant pressure by the specific heat at constant volume. $\frac{.2375}{.1685}=1.408$ and $\frac{1.408-1}{1.408}=0.2908$ the ratio; practically the last figure is dropped and 0.29 used. The logarithm of the quotient of $\frac{p}{P}$ must be used, when the operation will then be for, say 100 lbs. gauge pressure from 60° initial temperature.

$\frac{114.7}{14.7}=7.803$ log. 0.89225

Multiplied by exponent, 0.29

Index log. - - 0.2587525

The index of which is $1.8145 \times (461^\circ.2+60^\circ) = 945^\circ.71$ Fah. absolute temperature; from which must be deducted 461°.2, leaving 484°.5 as the temperature of compression by the Fahrenheit scale.

The limiting point of heat by the compression of air is unknown, but is probably at the pressure of liquefaction, which has not yet been found with pressures up to 15,000 lbs. per square inch.

Cooling from the expansion of compressed air is inversely in the same ratio as for compression; or, the temperature falls by the same scale that it rises.

As we have said above, the heat saturation point is probably at the pressure of liquefaction; so the cold extreme from expansion is probably at the absolutely zero of expansion or perfect vacuum; which is now accepted as the zero of absolute temperature 461°.2 below the zero of the Fahrenheit scale.

The difference of temperature by compression for equal increments of pressure, is much greater in the lower part of the compression scale than in the upper part, as for example the increase of temperature from atmospheric pressure to 1 lb. per square inch is 10 degrees Fah., while for an increase of 1 lb. pressure from 99 to 100 lbs. is but 2 4-10 degrees Fah. The differences of temperature when plotted on a pressure diagram form a parabolic curve from its axis at absolute zero and terminating at infinite pressure and temperature; the conditions within the limits of practice indicate this curve, as also its inverse order in the expansion of compressed air.

PATENTS GRANTED APRIL, 1899.

Specially prepared for COMPRESSED AIR from the Patent Office files by Grafton L. McGill, Washington, D. C.

622,424.—Apparatus for Heating and Agitating Air. L. P. Hager, Waltham, Mass. Assignor to Bay State Electric Heat & Light Co., Jersey City, N. J.

A hood, closed at the top and open at the sides, is pivoted on a support It consists of a series of floats separated from each other at the sides to form lateral openings located at an angle to the line of passage of the heated air and products of combustion. The lateral discharge of the heated air through the openings and against the floats causes the hood to revolve, such revolution accelerating the diffusion of the heated air and products of combustion throughout the apartment to be heated, the speed of rotation of the hood being regulated by the air supply.

622,576.—Pneumatic Tool. D. S. Waugh, Denver, Colorado.

A tool is carried by an outer shell, an inner shell being free to move longitudinally within the former. In the inner shell is located a reciprocating hammer provided with a piston head. Fluid under pressure is admitted through valve-controlled passages to the piston head, while another such passage admits pressure to a chamber at one end of the inner shell to effect the movement thereof. The handle is connected to the outer shell and to the valve controlling the admission of air to the inner shell.

622,344.—Valve for Compressors. F. W. Gordon, Philadelphia, Pa.

A valve cylinder having one of its ends opening into the compressor cylinder, is provided with discharge ports in its wall near such communicating end, the opposite end of the valve cylinder being in communication with the discharge-chamber. A closed valve piston reciprocating within the valve-cylinder is adapted to have its end co-operate with the discharge ports, while a tappet moves the valve piston to position to cover the ports.

623,357.—Pneumatic Apparatus for Raising Liquids. Wm. Evans, Manchester, England.

A tube contains a plunger to which latter is connected a piston, while packing, carried by the plunger, extends across the space between said plunger and the tube.

623,135.—Check Valve for Air. G. E. Cordeau, New York, N. Y.

The body-portion is provided with a longitudinal passage-way through the centre, and an enlarged valve-chamber at both its upper and lower ends, the chambers being connected by the passage-way. A tubular valve-stem has a sliding movement within the passage-way, and is closed at its upper end and provided with an orifice for admission of air. This sliding stem unites an upper and lower disk-valve which close alternately upon seats formed in their respective chambers. The lower valve is provided on its outer face with a hollow cone of soft rubber.

623,509.—Pneumatic Despatch System. L. G. Bostedo, Chicago, Ill.

The despatch-tube is provided with valves for closing the tube, such valves being separated from each other so as to admit the carrier between them, one of the valves being normally closed and the other opened. The pressure chamber has a piston operatively connected with the open-valve, and a pipe in constant communication with the despatch tube near the closed valve and also with said pressure chamber. The despatch-tube and pressure chamber being maintained under less than atmospheric pressure, one of the valves is normally held open and the other closed, the traverse of the carrier operating to reverse their positions.

623,510.—Pneumatic Despatch-Tube System. L. G. Bostedo, Chicago.

Two gates or valves, one normally open and the other closed and operated by motors, are located at separate points within the main despatch tube. Pipes or passages are located in direct communication between the main tube and the motors, by which means the variations of pressure between the carrier and the gates, caused by the movement of the former in the tube, directly operates the motors and valves. A by-pass is arranged around the normally open gate and is controlled by a valve, the latter being actuated, by the compression of air by the carrier, to equalize the pressure on both sides of the normally open gate when closed, to permit the same to reopen The normally closed gate has its motor connected by a pipe with the main tube, whereby the rarefaction of the air in the tube behind the advancing carrier opens the gate to permit the discharge of the carrier.

622,750.—Air Brake. C. F. Bayne, Lafayette, Indiana.

This invention relates to the class of air brakes employing a train pipe extending beneath the train, in which air is maintained at a predetermined pressure to automatically apply the brakes by a reduction of such pressure A supplemental signal pipe extends continuously through the train, the pressure of which is controlled by angle cocks on each car and engine. Means are provided for the engineer to lock these angle cocks in open position, except the one at the rear end of the train, which is locked closed. The locking devices are located in the signal pipe, the angle cocks in which latter are connected to those of the train pipe. The two sets of cocks are thus operated in unison and in pairs, by mechanism controlled by the engineer, the closing of such cocks setting the brakes.

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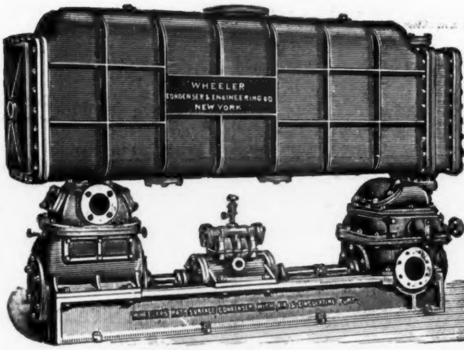

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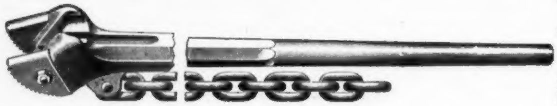

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